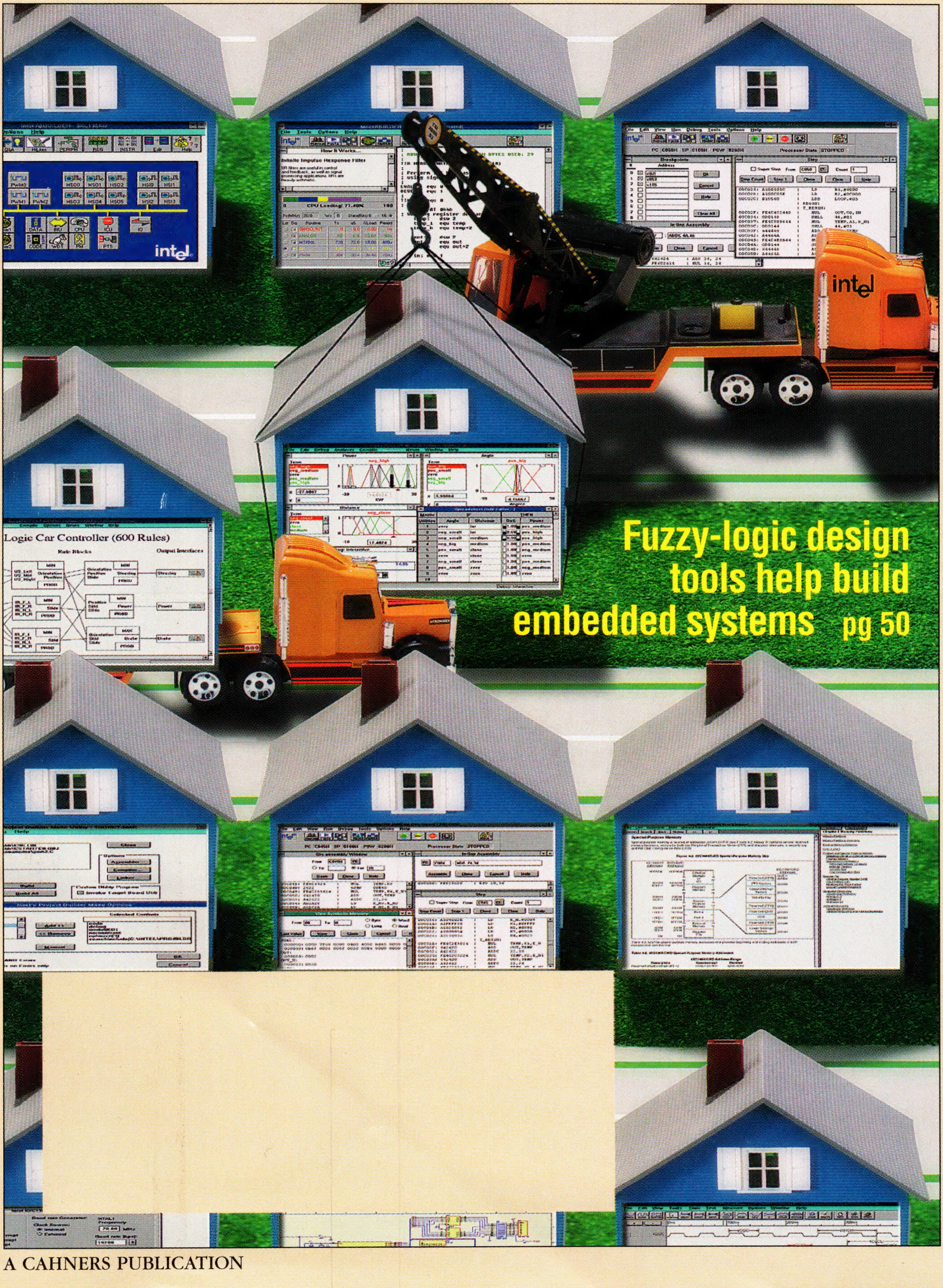
EDN®

27 SEP 1994

THE DESIGN MAGAZINE OF THE ELECTRONICS INDUSTRY



Fuzzy-logic design tools help build embedded systems pg 50

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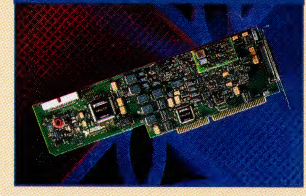

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Negatrons enrich filter, oscillator designs

Op-amp rectifier signals input state

All-digital circuit fires triacs

Simple timer exploits op-amp bias current

Speedy Spice subcircuit models lossy line

EDA Inc: One-trick ponies? pg 120

Fuzzy logic: The μP of tomorrow? pg 123

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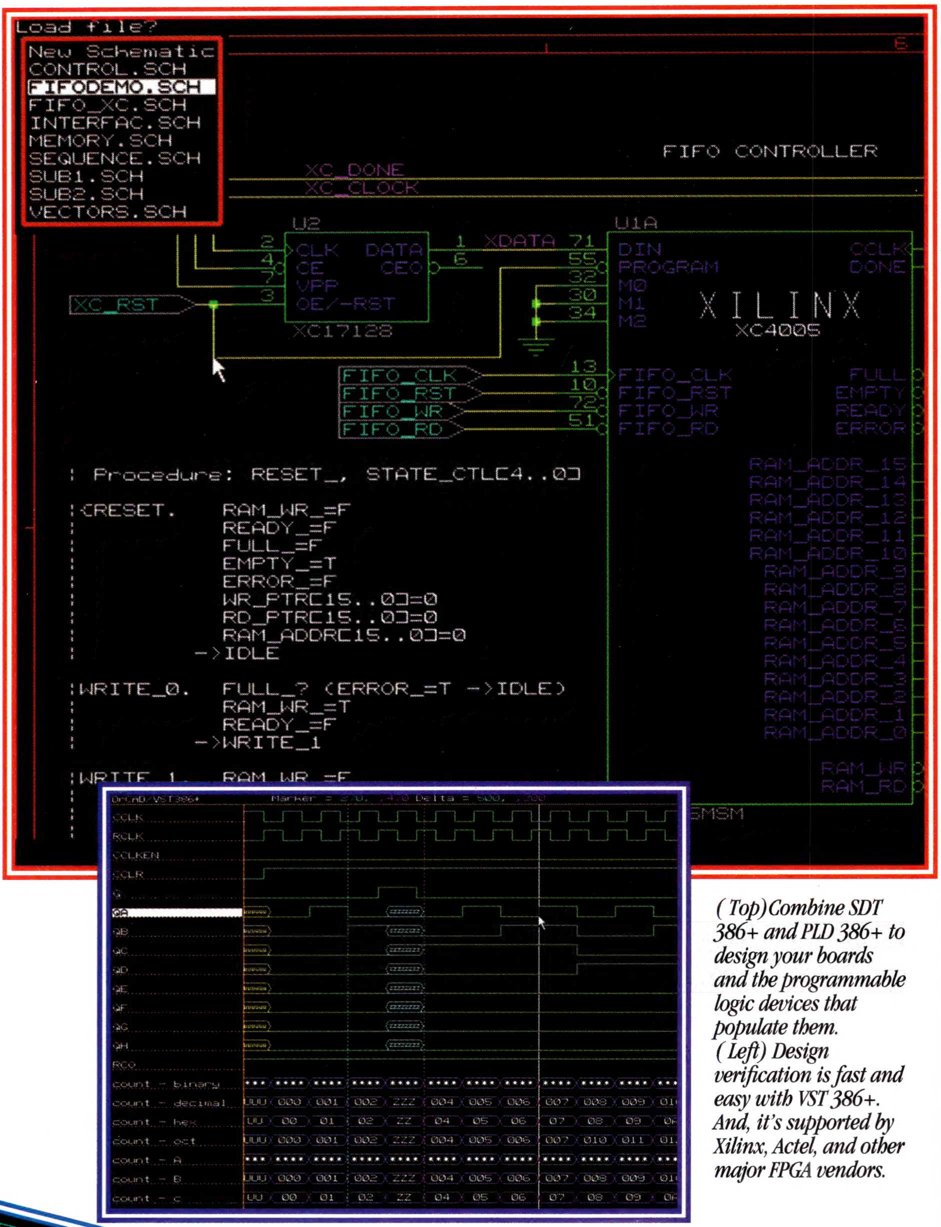

```
; Procedure: RESET_, STATE_CTL[4..0]

;<RESET.      RAM_WR_=F
;             READY_=F
;             FULL_=F
;             EMPTY_=T
;             ERROR_=F
;             WR_PTR[15..0]=0
;             RD_PTR[15..0]=0
;             RAM_ADDR[15..0]=0
;           ->IDLE

;WRITE_0.     FULL_? (ERROR_=T ->IDLE)
;             RAM_WR_=T
;             READY_=F
;           ->WRITE_1

;WRITE_1.     RAM_WR_=F
```

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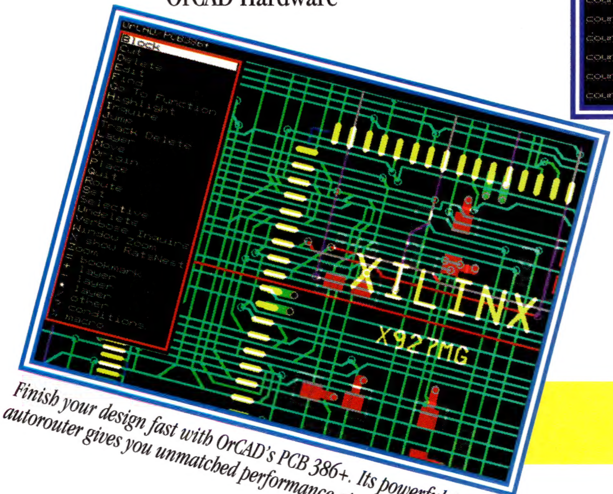

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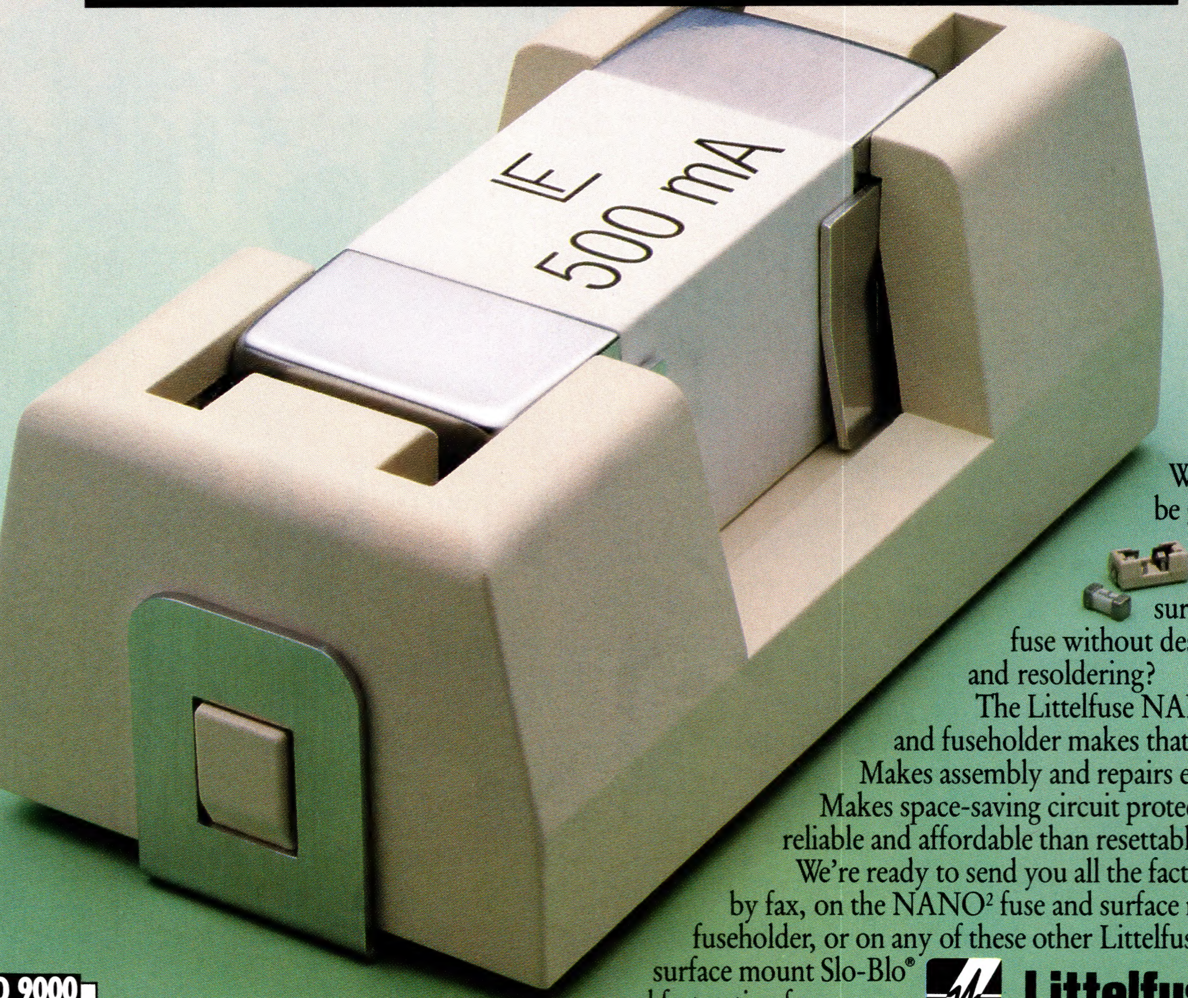

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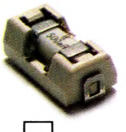

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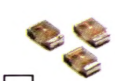

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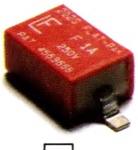

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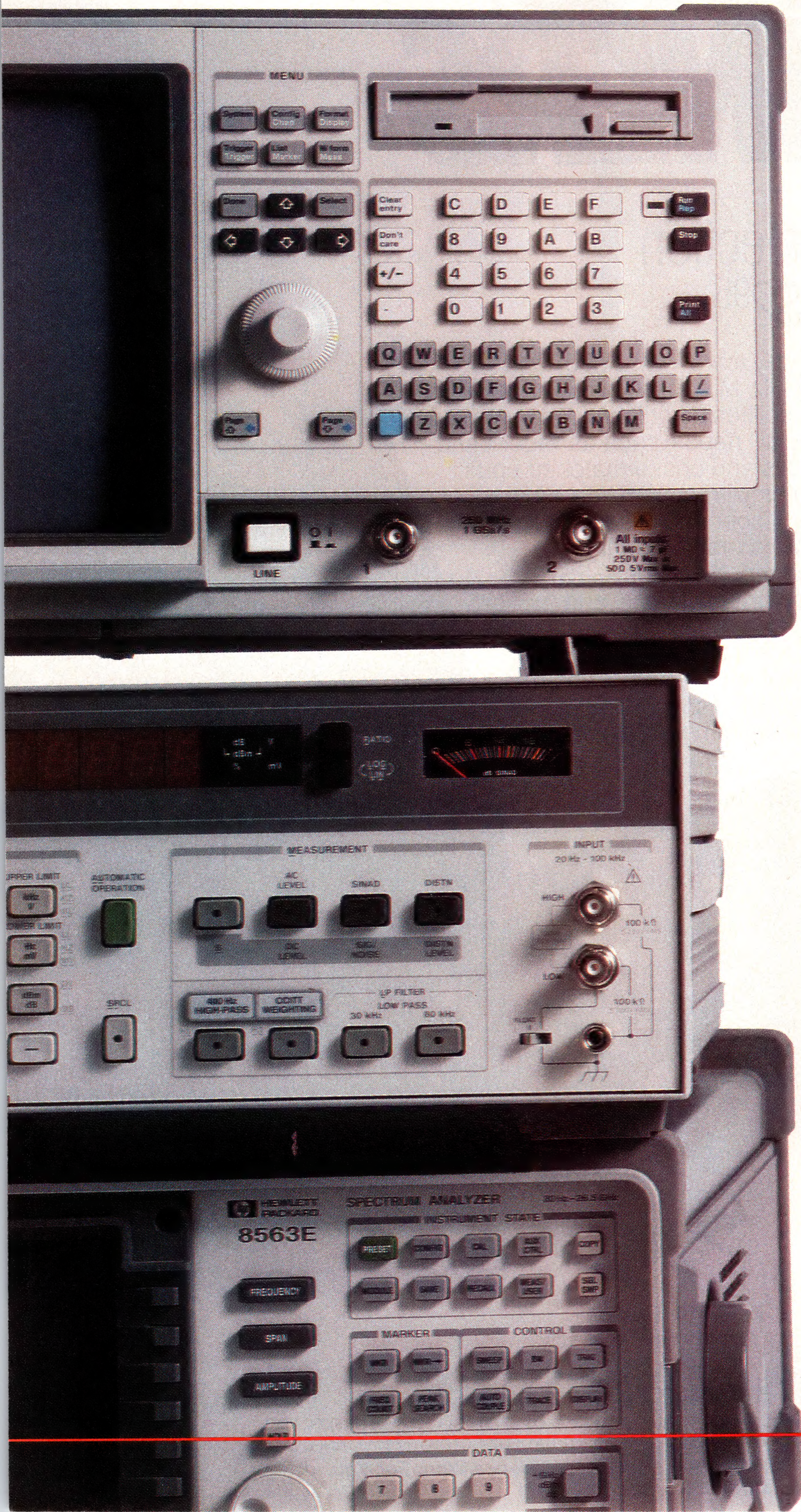

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On the cover: Thanks largely to easy-to-use design tools, fuzzy logic is helping engineers build complete embedded systems. See our Special Report, beginning on **pg 50.** (Photo courtesy Intel Corp)

SPECIAL REPORT

Fuzzy-logic design tools help build embedded systems 50

Fuzzy logic is slowly catching on, and fuzzy design tools are getting better: They don't just help design fuzzy logic, they let you create complete embedded systems.—*Gary Legg, Senior Technical Editor*

DESIGN FEATURES

Asynchronous conversion thwarts incompatibility in sampling A/D systems 83

By using asynchronous sample-rate conversion, you can eliminate the problem of repeated or dropped signals that can occur when interconnecting systems with incompatible clock rates.
—*Robert Adams, Analog Devices Inc*

Electromagnetic theory imposes constraints on pc-board design 93

An understanding of electromagnetic effects often leads to a better pc-board design than prototyping and debugging in the lab using traditional rules of thumb.—*Gregory S Seltzer, Mentor Graphics Corp, and Reza Ahy and Monica Razmi, Stanford-Berkeley Associates*

DESIGN IDEAS

Negatrons enrich filter, oscillator designs 67
Op-amp rectifier signals input state 68
All-digital circuit fires triacs 70
Simple timer exploits op-amp bias current 70
Speedy Spice subcircuit models lossy line 72
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ATMEL FPGA IS AS VERSATILE AS MADISON SQUARE GARDEN

Cache Logic™ capability opens design architecture while reducing part count

Most systems contain millions of gates of logic but use only a small fraction of them at any given moment. Meanwhile, the unused circuits still draw power and waste space while they wait to perform the one operation for which they are programmed.

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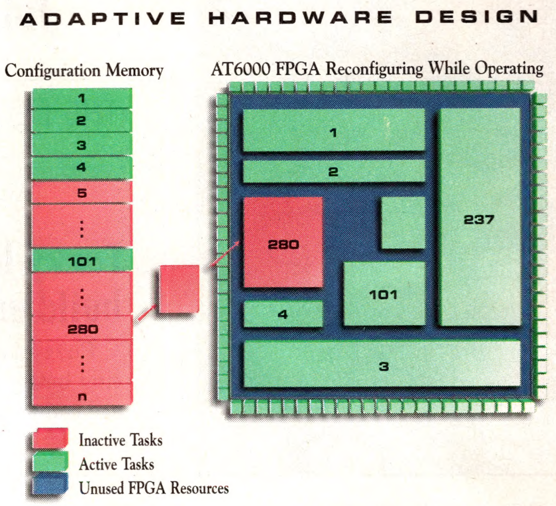
THE VIRTUAL TIME-SHARE LOGIC CENTER

Imagine an FPGA that works like Madison Square Garden. This major metropolitan convention center capitalizes on every square foot of real estate by hosting many unrelated events in the same meeting areas each day. Management shuffles one group out of a room, rearranges the furniture, and brings in the next group so efficiently that each group is oblivious to the next. With Atmel FPGAs, your support logic can work the same way.

The AT6000 Series' unique Cache Logic capability means that logic gates can be time-shared like the meeting space in an event center, so functions get out of the way when you don't need them. As a virtual time-share logic center, an AT6000 FPGA can be reconfigured to perform one special task after another in real time, while inactive operations wait in a single, low-cost media such as an EPROM or hard disk, so you make the most of every square millimeter of your board. With Cache Logic, a conventional 25,000-gate design that needs only 5,000 gates at any given machine cycle can use a less expensive 5,000-gate AT6005 and store the idle 20,000 gates for later use. Only a fraction of the circuit is active at any given time, and only the functions that are currently loaded in the FPGA cache consume logic real state and power.



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To receive a free demo disk and literature packet explaining more about Atmel's FPGAs with Cache Logic, call 800-365-3375 extension 694.

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TECHNOLOGY UPDATE

Analog HDLs advance speed and enhance modeling flexibility 37

Analog HDLs have been commercially available for years, but their acceptance in mainstream analog and mixed-signal design may coincide with an industry-standard language—or two.
—Doug Conner, Technical Editor

EDITORIAL

Reverse-engineering of the third kind 31

Reverse-engineering has a bad name. But, like most other things in life, this practice is neither all black nor all white.
—Steven H Leibson

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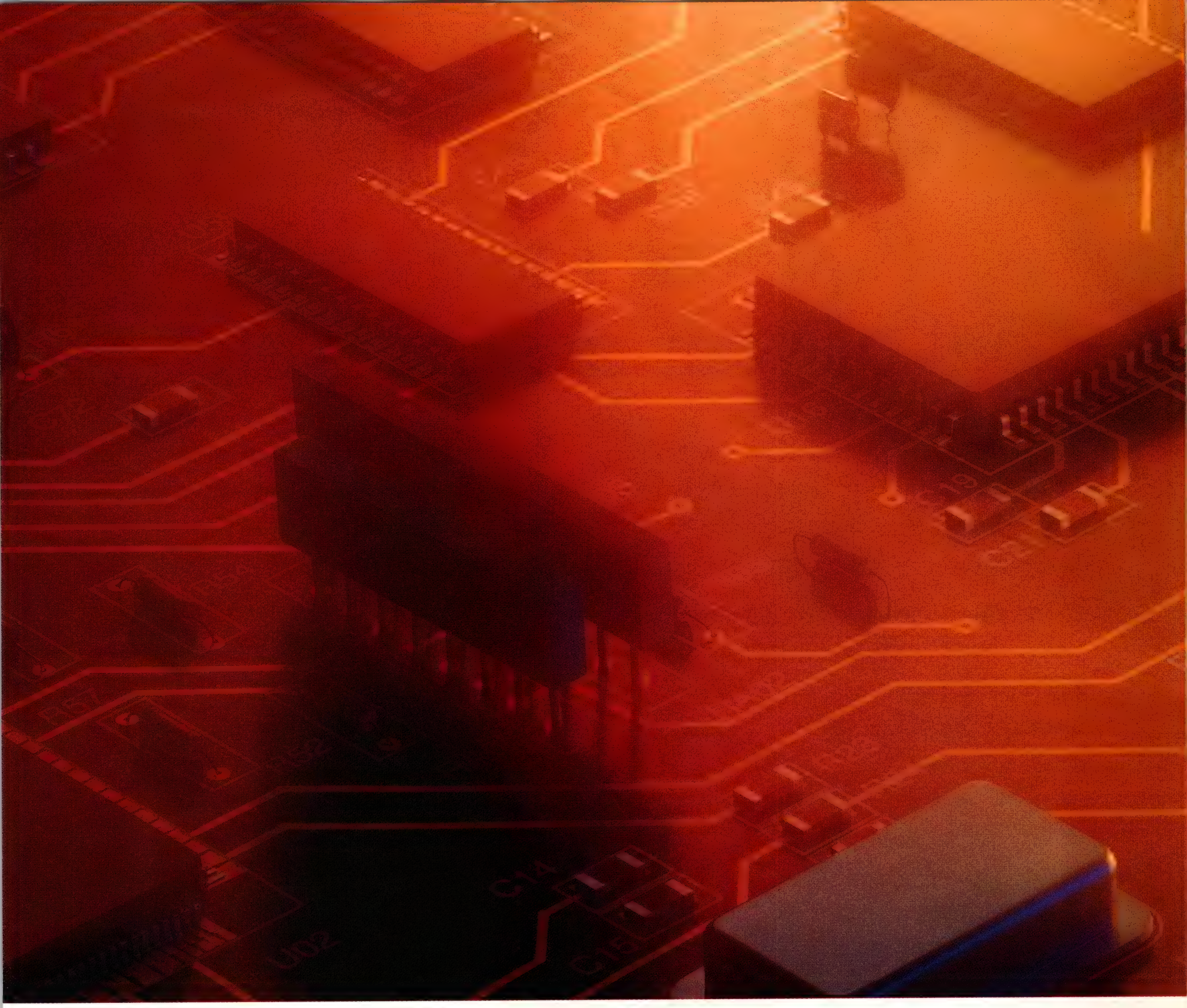

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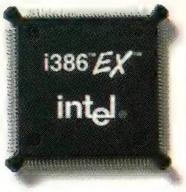

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And designing with an embedded Intel386 processor

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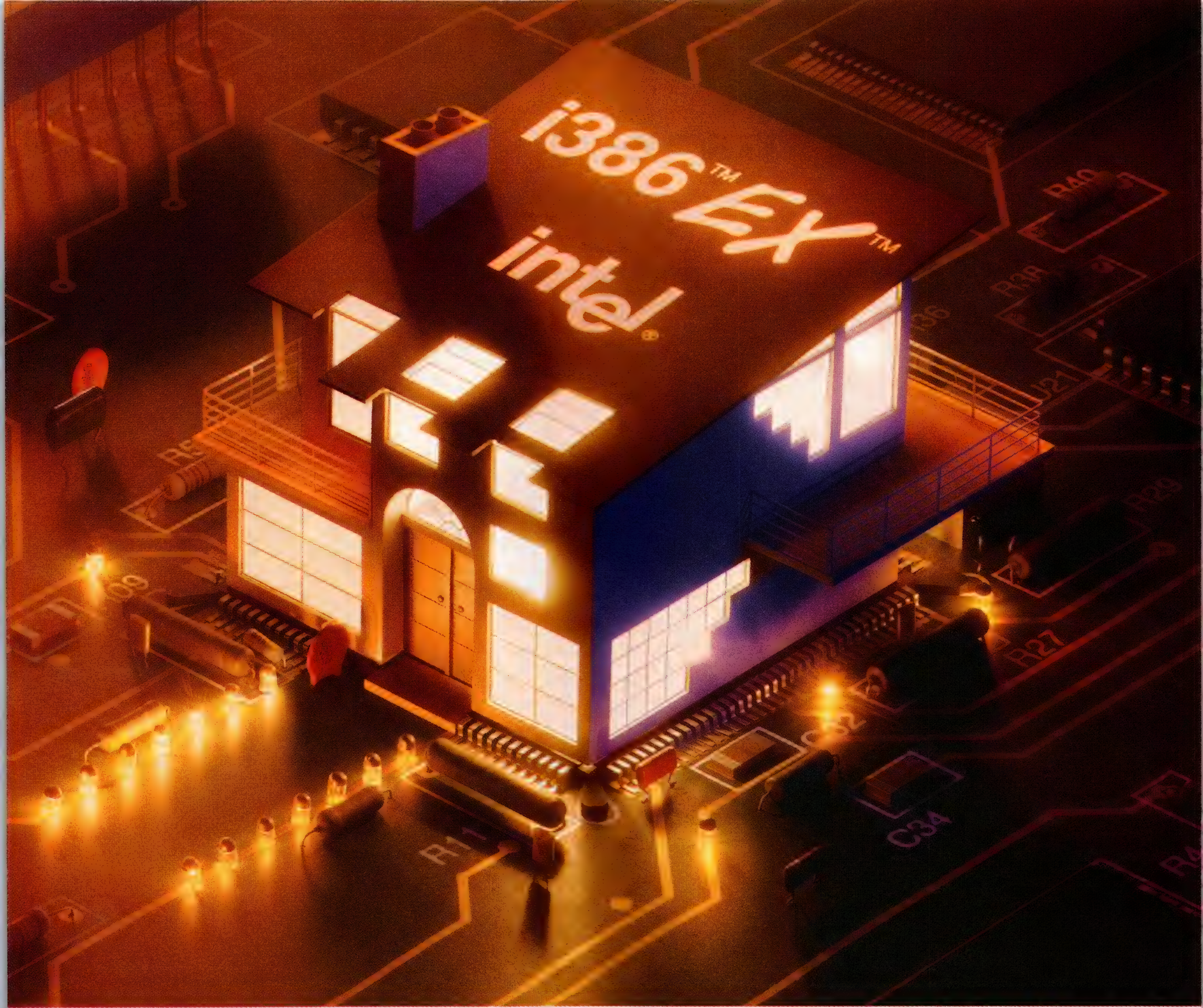

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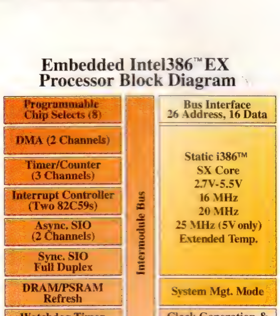
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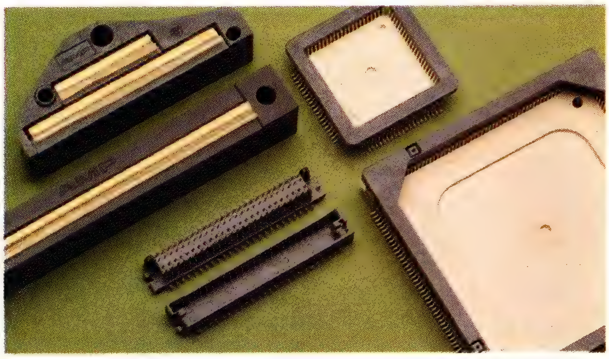

AMP fine-pitch solutions are available for designs requiring sub-0.050", sub-2mm centers. Metristak board-to-board stacking connectors on 1mm centers; LGA, MCR, and PQFP sockets; FPC connectors on 1mm and 0.5mm centers; AMPLIFLEX elastomeric package- and board-to-board connectors for pitches as fine as 0.025".

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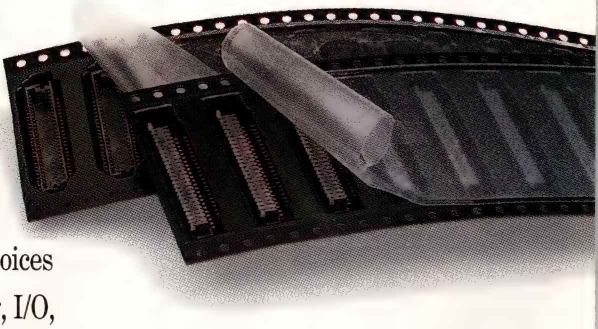

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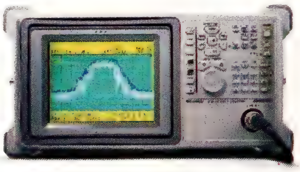

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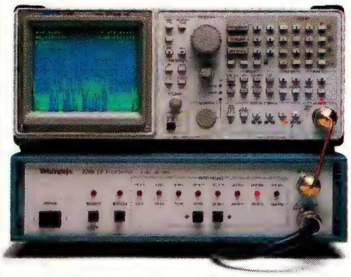

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CIRCLE NO. 66

2EA-2853

EDITED BY FRAN GRANVILLE

Verification tools, merger shift DAC spotlight from ESDA

The highlight of last year's Design Automation Conference (DAC) was electronic system-design automation (ESDA). However, ESDA was almost a no-show at this year's conference, held last month in San Diego. Instead, verification tools, such as model verifiers, emulators, and rapid prototypers, took center stage.

Last month, Cadence Design Systems acquired Redwood Design Automation which had merged with Comdisco Systems. The two companies will operate as the Alta Group, a business unit of Cadence. Redwood was a star of last year's show for software that merged the high-level design of hardware and software systems. While Redwood showed its capabilities at this year's DAC, rumors surfaced that the company's investors hastened the sale. The investors feared that the ESDA market would fail to materialize before a flood of ESDA start-ups saturated the nascent market.

Among the announcements that made verification the theme of DAC was one from Synopsys. The company, in cooperation with Intel Corp, will offer synthesizable peripheral-component-interconnect (PCI) controller modules that you can use as building blocks in ASIC designs. Available in the fourth quarter of this year, the PCI Design Kit will include the synthesizable PCI controller module, a PCI bus interface model for system verification, and the PCI test suite to check a design's compliance with test protocols.

Several vendors presented verification tools at DAC. For example, electronic-design-automation start-up Chrysalis introduced its Insight series of state-machine and data-path analysis tools. IBM's Altium Co, previewed BoolesEye ($30,000), a formal verification tool that mathematically compares register-transfer-, gate-, and transistor-level circuit descriptions.

Another start-up, Arkos Design Inc, premiered an early version of its Pegasus IC-emulation system. Unlike previous emulators, Pegasus uses an array of 64 custom ASICs that can be programmed to emulate as many as 200,000 gates (about $115,000). A 25,000-gate system is also available. According to Arkos, the ASIC-based approach reduces the time to compile a design to one hour compared with five to 10 hours using field-programmable gate arrays (FPGAs).

Aptix showed its Explorer series of emulators that combine FPGA- and programmable-interconnect-based circuit emulation with the ability to accept components and subsystems, such as microcontrollers, memories, and peripherals, on the emulator. The result is a family of flexible emulators that run as fast as 50 MHz, with prices starting at $40,000.

Zycad and Quickturn introduced rapid-prototyping systems. Although emulators allow you to debug a model via programmable access to internal nodes, rapid-prototyping tools verify designs by allowing you to plug the model in to the target system. Zycad's 250,000-gate Paradigm RP (about $50,000) includes software to map your design onto Altera FPGAs, which are embedded in the Paradigm RP, or onto custom prototype hardware. Quickturn's Logic Animator ($90,000) accommodates subsystems and cooperates with logic analyzers to produce a prototype you can use to debug your system.—by Michael Markowitz

Alta Group, Foster City, CA, (415) 574-5800. **Circle No. 410**

Altera Corp, San Jose, CA, (408) 894-7110. **Circle No. 411**

Altium Co, San Jose, CA (408)534-4100. **Circle No. 412**

Aptix, San Jose, CA, (408) 428-6200. **Circle No. 413**

Arkos Design Inc, Scotts Valley, CA, (408) 461-8100. **Circle No. 414**

Cadence Design Systems Inc, San Jose, CA, (408) 943-1234. **Circle No. 415**

Chrysalis, Andover, MA, (508) 475-7700. **Circle No. 416**

Intel Corp, Santa Clara, CA, (408) 987-8080. **Circle No. 417**

Quickturn, Mountain View, CA, (415) 967-3300. **Circle No. 418**

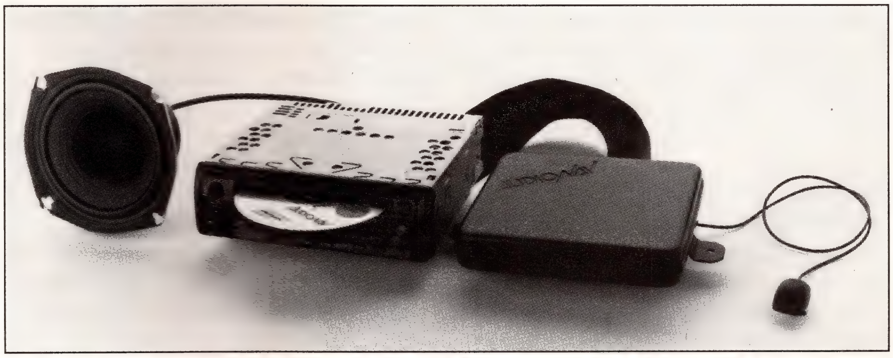
Synopsys, Mountain View, CA, (415) 962-5000. **Circle No. 419**

Zycad, Fremont, CA, (510) 623-4400. **Circle No. 420**

System offers voice-activated navigation

Lernout & Hauspie Speech Products, a developer of multilingual voice-input and -output technologies, has signed a licensing agreement with Amerigon Inc, a worldwide provider of automotive electronic components. Under terms of the agreement, Amerigon will incorporate Lernout & Hauspie's integrated-alphabet and isolated-word speech-recognition technologies in AudioNav, Amerigon's voice-activated audio-navigation system.

The technology allows AudioNav users in automobiles—traveling as fast as 60 mph and with closed or open windows—to "speak" to the system and obtain directions to their destinations.



Amerigon will incorporate Lernout & Hauspie's integrated-alphabet and isolated-word speech-recognition technologies in AudioNav, Amerigon's voice-activated audio-navigation system. The system comprises a small electronic module and a microphone, which connects to a compatible audio CD player. The CD contains operating software, map data, and speech-recognition software.

The system comprises a small electronic module and a microphone, which connects to a compatible audio CD player. The CD contains the operating software, map data, and speech-recognition software. The system aims at replacing expensive, awkward, and potentially dangerous keyboards and display monitors. The technology can work with many low-cost, general-purpose DSPs, including the Analog Devices AD210X that AudioNav uses.

—by Fran Granville

Lernout & Hauspie Speech Products, Woburn, MA, (617) 932-4118.

Circle No. 421

DEC renames business storage unit to target desktop industry

In a move that reflects the changing market for disk drives, Digital Equipment Corp has changed the name of its OEM storage-business unit and has introduced its first drives that are intended primarily for desktop computers. Avastor, the new business and brand name, distinguishes Digital's OEM storage business from the company's more prominent systems business, according to Marketing Vice President Jack Sharp. Three new disk drives bearing the Avastor brand, one of which uses magneto-resistive (MR) heads, answer desktop computing's increasing need for higher capacity and higher performance drives, Sharp says.

The new drives—all in the 3.5-in., 1-in.-high form factor and ranging in capacity from 550 Mbytes to 2.2 Gbytes—do not indicate DEC's movement into the desktop market, according to Sharp, as much as they reflect the desktop market's movement into DEC's areas of strength. According to market-research company Dataquest, standard desktop systems running data-intensive applications, such as multimedia and desktop publishing, will offer 540 Mbytes of storage by year-end and 1 Gbyte in 1995. Disk drives from Avastor have targeted the high-capacity, high-performance market segments since the business unit was formed in 1991. Until recently, however, most of those drives have found use in larger systems, such as servers.

The three introductions from Avastor, the Capella series, provide short seek times, fast data-transfer rates, and high reliability. Capella 3221, with MR heads and 2.2 Gbytes of capacity, has a seek time of 8 msec and a data-transfer rate of 7.5 Mbytes/sec. The other two drives—Capella 3110 (1.1 Gbytes) and Capella 3055 (550 Mbytes)—have seek times of 8.5 msec and data rates of 5.2 Mbytes/sec. MTBF is 800,000 hours for the 3221 and 700,000 hours for the other two drives. All of the drives operate at 5400 rpm, less than the 7200 rpm of Avastor's highest performance drives. The two lower capacity drives, Capella 3110 and 3055, will be available in the third quarter at single-unit evaluation prices of $1125 and $765, respectively. Avastor expects the Capella 3221 to be available in the fourth quarter for a single-unit price of $1720.—by Gary Legg

Avastor, Shrewsbury, MA, (800) 377-3475. **Circle No. 422**

New group addresses PCI passive backplane

Four industrial-computer manufacturers have formed a technical and marketing consortium that will define a specification for PCI-based passive backplanes and CPU cards for industrial PCs. The specification will facilitate plug-and-play compatibility of vendors' components and will assist migration from ISA- to PCI-based industrial PCs.

Charter members of the PCI Industrial Computer Manufacturers Group (PICMG) include I-Bus PC Technologies, Teknor Microsystems, Texas Microsystems, and Trenton Terminals. The four companies are recruiting other manufacturers to help formulate, review, and comment on the specification. The PCI standard, which Intel developed, includes specifications for motherboard-based PCs. It does not include passive-backplane systems, which commonly find use in industrial settings.—by Gary Legg

I-Bus PC Technologies, San Diego, CA, (619) 974-8472. **Circle No. 423**

Teknor Microsystems Inc, Montreal, PQ, Canada, (514) 437-5682. **Circle No. 424**

Texas Microsystems Inc, Houston, TX, (713) 541-8200. **Circle No. 425**

Trenton Terminals Inc, Duluth, GA, (404) 381-6031. **Circle No. 426**

TI aims DSPs at growing hard-disk market

Texas Instruments, the dominant supplier of DSPs for use in hard-disk drives, has announced that it intends to maintain its leadership by combining the functions that are now implemented in separate DSPs, ASICs, and linear devices into single chips. Although DSPs go only in disk drives of the highest capacity and performance, TI Hard-Disk Strategy Manager Alex Gorjanc says DSP functions will migrate downward into drives that are less than state of the art. DSP usage in disk drives will triple in three years, Gorjanc predicts.

DSPs find their calling in the control algorithms that are essential in disk drives with multiple platters, high speed (6400 to 7200 rpm), and high capacity (1 Gbyte or greater). Their processing power is necessary for sophisticated servo control that takes into account such factors as head acceleration and deceleration, resonance, and thermal variation. But servo control uses only about 15% of a DSP's processing power, Gorjanc claims, leaving 85% for other functions, some of which conventional microcontrollers now perform. The ability of DSPs to take on new functions and to eliminate the need for a separate microcontroller practically guarantees an increased role for DSP in an increasing number of drives, Gorjanc says.

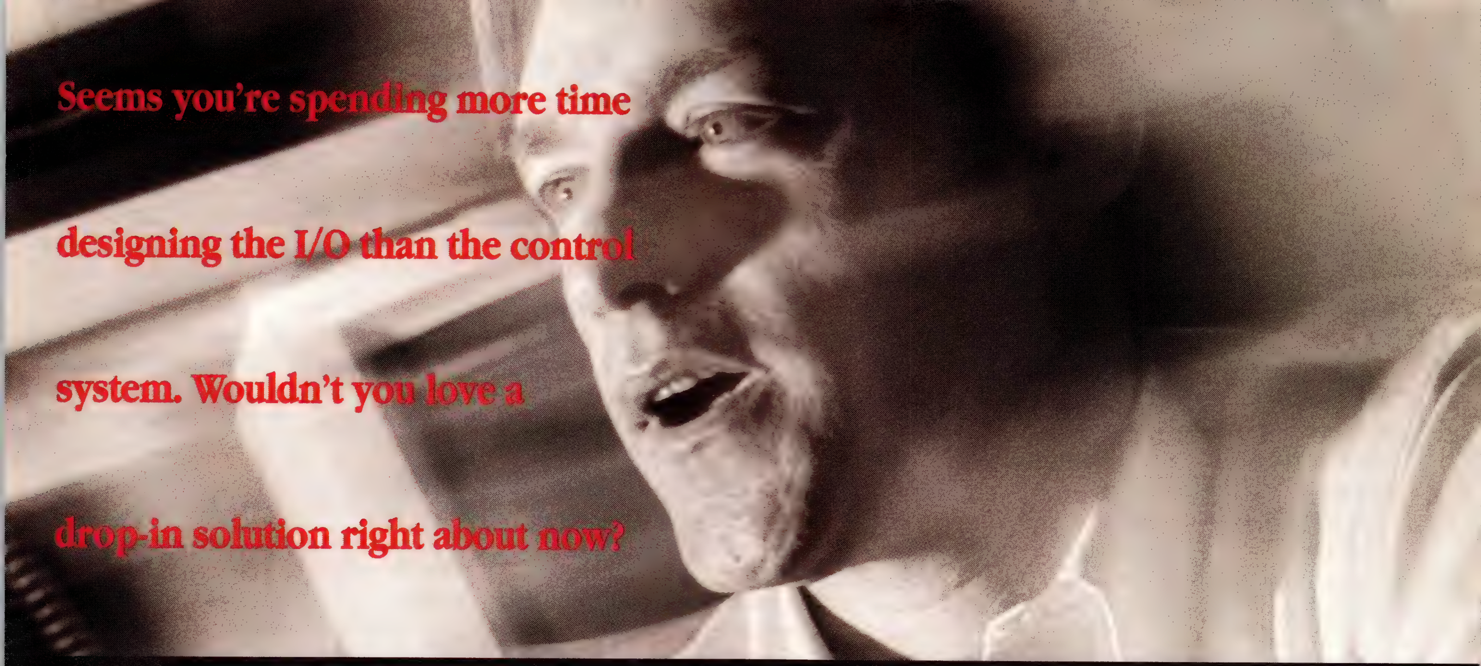
TI's DSP strategy for disk drives, according to Gorjanc, is to reduce costs to disk-drive manufacturers with single-chip offerings that provide as much capability as the manufacturers need, but no more. TI will provide various levels of customization to suit requirements for unit cost and development time.—by Gary Legg

Texas Instruments Inc, Dallas, TX.

Circle No. 427

Servo motor acts as drop-in stepper-motor replacement

The ServoStepper brushless servo motor for OEMs offers servo performance at open-loop microstepper prices. The ServoStepper, designed as a drop-in replacement for stepper systems, provides better stiffness than a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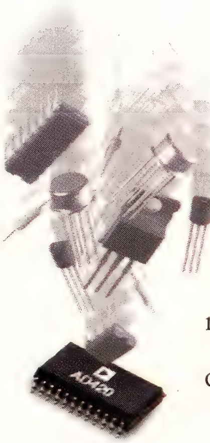

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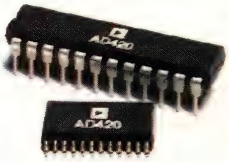

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CIRCLE NO. 73

stepper because its dead band is smaller, and it provides a constant restoring torque for errors in shaft positioning. A stepper motor's restoring torque is sinusoidal, which can be negative for large position errors and can cause the stepper to lose steps.

The ServoStepper employs a DSP core for motor control. Proprietary embedded software can execute complex functions, such as input filtering, PIV and feed-forward algorithms, vector commutation, and output filtering. In addition, the ServoStepper has two to five times the power of a stepper motor. The result is a 26 to 71% improvement in throughput. Bundled packages, which include a drive and a brushless motor delivering 160 to 600 oz-in. of torque and as much as ⅔ hp, range from $529 to $699.—by John Gallant

Teknic Inc, Rochester, NY, (716) 546-3212. **Circle No. 428**

MicroTouch offers touchscreen with privacy shield

MicroTouch Systems Inc has announced the PrivacyTouch sensor, a privacy-shielded touchscreen for transaction-based kiosks and automatic teller machines. With the sensor, users can view on-screen data from directly in front of the terminal; bystanders see only a blank screen. The sensor comprises an integrated, all-glass capacitive touchscreen bonded to a light-control filter. The filter comprises a thin plastic film containing closely spaced, black vertical microlouvers that simulate a tiny Venetian blind. The louvers prevent users at the side of the terminal from viewing the emitted light from the CRT display. Samples of the system, including a sensor and a controller, cost $995 each.—by Fran Granville

MicroTouch Systems Inc, Methuen, MA, (800) 642-7686. **Circle No. 429**

Utility company will use Intellon components

Integrated Communications Systems Inc, Atlanta, will use Intellon Corp's CEBus-compliant products as the basis for American Electric Power's (AEP) remote electric meter-reading and electric energy-management systems. Early next year, the utility company will begin to install the Transtext advanced energy-management system in 25,000 homes in Indiana, Kentucky, Michigan, Ohio, Tennessee, Virginia, and West Virginia.

Using Intellon's spread-spectrum-carrier technology, the AEP systems allow residents to control central heating and cooling systems, electric water heaters, and appliances. Residents will be able to respond to changing price signals that reflect the utility's costs of producing and providing electricity.—by Fran Granville

Intellon Corp, Ocala, FL, (904) 237-7416. **Circle No. 430**

Neural-net OCR reduces production costs of electronics

The ID-2020 optical-character-recognition (OCR) system, a neural-network-based, omnifont system, reduces the costs of identifying, setting up, and reworking assembly errors for electronics manufacturers.

The device comprises an 80486 PC host, a 700-MIPS image processor, an image-processing library, and pretrained neural networks for recognizing generic industrial markings. The neural networks combine feed-forward, back-propagation-of-errors, and radial-basis methods into three parallel networks. Each network makes its best guess of a character, including a confidence level. The device costs $15,999.

—by Fran Granville

Identek Corp, Orange, CA, (714) 633-1431. **Circle No. 431**

Alliance broadens digital video transmission

Communications giant Scientific-Atlanta Inc and IC developer Broadcom Corp have banded together to develop ICs that multiply the number of video signals an analog channel can carry. The alliance's 256 QAM chip set can send 8 bits of digital data for every hertz of a channel's analog bandwidth by using quadrature amplitude modulation (QAM). The result is that a standard 6-MHz analog cable video signal can carry 40 Mbps of digital data, enough for more than 25 MPEG-compressed digital video signals.

The alliance has demonstrated its chip set and has been conducting field tests with Time Warner Cable in Orlando, FL. Features of the set include all-digital intermediate-frequency data demodulation, signal acquisition within 100 nsec, immunity to phase noise and microphonics, and an ability to track through instantaneous changes in transmission characteristics. The alliance plans to offer the chip set for sale when fully released.

—by Richard A Quinnell

Broadcom, Los Angeles, CA, (310) 433-4490. **Circle No. 432**

Scientific-Atlanta Inc, Atlanta, GA, (404) 903-6306. **Circle No. 433**

SHORTS

Allegro MicroSystems Inc offers seven product families. The families comprise 21 power multichip modules that handle up to 1 kW. The company claims this is 100 times the processing power of conventional monolithic systems. Allegro Microsystems Inc, Worcester, MA, (508) 853-5000. **Circle No. 434**

MIT issues software codes for Internet privacy. The Massachusetts Institute of Technology is offering for noncommercial use a free public software package that allows users to send private coded messages on electronic networks in the United States. The software, PGP (for "pretty good privacy") version 2.6, uses the RSAref cryptographic tool kit from RSA Data Security Inc, Redwood City, CA. The system lets users sign messages in an unforgeable way and to send confidential messages that only the intended recipients can read without any need to exchange secret keys beforehand. Massachusetts Institute of Technology, Cambridge, MA, (617) 253-2700. **Circle No. 435**

We could never measure up to
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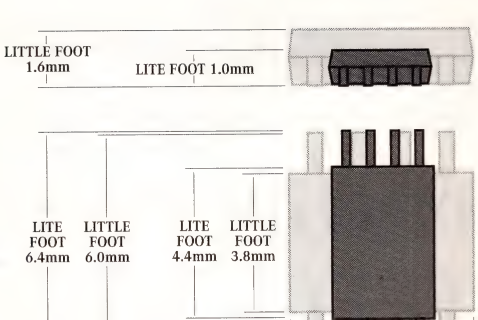
for something smaller.

Introducing LITE FOOT. Everything you like about LITTLE FOOT power MOSFETs, only smaller.



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Siliconix, the pioneer in 8-lead SOIC power MOSFETs, has redefined the performance of ultra-miniature, surface-mount power. The result is a new family of n-channel and p-channel devices that delivers on-resistance as low as 50 mΩ. Further, LITE FOOT features TSSOP surface-mount compatibility, and offers gate drive voltages as low as 2.7 V and currents as high as 4.2 A.

In short, LITE FOOT is the smallest discrete power MOSFET in the world. It occupies only 6.4 x 3.0 millimeters of board space. And at a remarkable 1.1 mm high, it's the first power

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Si6956DQ	Dual N-Ch	20	100	2.5
Si6433DQ	Single P-Ch	-12	75	3.5
Si6447DQ	Single P-Ch	-20	100	3.0
Si6953DQ	Dual P-Ch	-20	200	1.7
Si6542DQ	Complementary N-Ch P-Ch	 20 -20	 100 200	 2.5 1.7

* On-Resistance shown at V_{GS} = 10 V, except Si6433DQ shown at V_{GS} = 4.5 V

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So if your designs keep shrinking, but your power management needs keep getting bigger, LITE FOOT is the solution.

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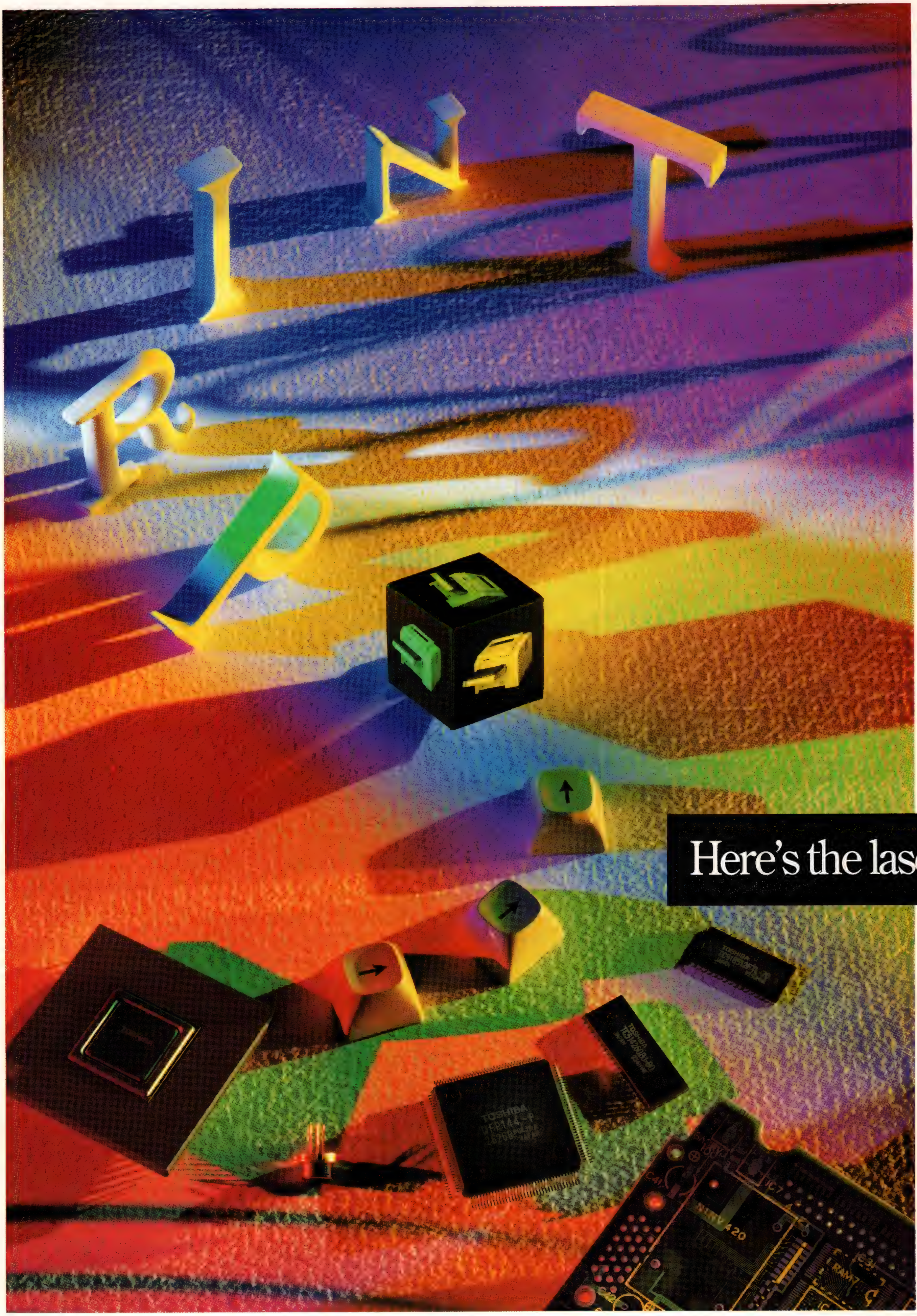
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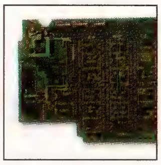
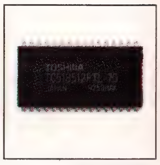
What's the story on Toshiba? System solutions.


Printed Circuit Board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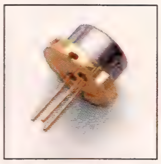
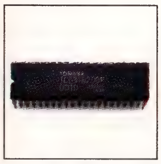
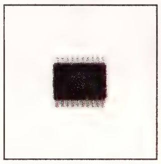
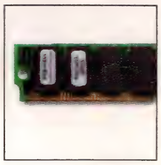

Visible Laser Diode

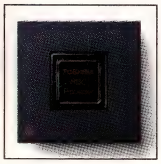

Mask ROM

ASIC


Logic

Memory Cards


DRAM Module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DRAM

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CIRCLE NO. 77

Update your files

In “Technique eases design of high-order PLLs” (*EDN*, June 9, 1994, pg 172), the **box** “How to get a copy of the programs” lists an incorrect phone number. Phone (505) 678-5889 to receive copies of the programs. Or you can review a demonstration program by logging on to the *EDN* BBS: (617) 558-4241 with modem settings 300/1200/2400 8,N,1. Access MS681Z.ZIP on the /freeware Special Interest Group.

Expect success

I’ve probably read several hundred *EDN* editorials, but the epistle “Raise your expectations” (February 3, 1994, pg 18) is the first one compelling enough for me to respond to in writing.

Your editorial is exactly on target, and I expect that many engineers will relate to it from personal experience. The experience is certainly true in my case.

Many years ago when I worked for a New Jersey communications manufacturer, I was given the task of mating a new tone-coded squelch system with an existing two-way mobile radio system. The problem was that the mating could not be done internally in the mobile radio. The squelch system (a companion piece of equipment) had to interface with the mobile radio externally, and the only access was an octal connector on the rear panel and a microphone connect on the front panel. As I recall, the octal connector brought out several test points, including B+, ground, and detector audio. Seemingly simple at first glance, the required interface between the squelch system and the radio was actually a nightmare that no one had been able to solve—including the chief engineer and the company president, also an engineer.

Despite previous lack of success, this proved to be my test case to see if I was really worth the big money the company had been paying me. The clear implication was that I had better come up with a solution to the problem...or else! Because I was married and had two young children to support, the challenge certainly raised my expectations.

I spent three days (and a couple of long nights) doing nothing but drawing schematics, which I subsequently balled up and tossed into the wastebasket. At the end of the third day, I apparently understood all of the circuit nuances so well that a sudden awareness—possibly divine—led me to an interface solution that I knew would work. I spent the next two hours drafting a simply gorgeous schematic, which I then laid in front of the chief engineer. After perusing the drawing for about 30 seconds, he ripped it off his desk and ran into the president’s office shouting, “Look what Dave did!” I not only got to keep my job, but I also received a $1000 raise on the spot. Such largess in the early 1960s was quite a vote of confidence.

My personal aside leads me back to your editorial. If I had simply been instructed to “see what I could do with the problem,” my expectations of success would not have been very high. Obviously, I had a very clear-cut goal. Not all goals carry such emotional baggage, but the premise is still valid. If a person or group is not expected to succeed, the resulting effort is likely to fail. In a group situation, a collective expectation of success is needed, and the group leader must instill this expectation in each individual, along with a spirit of cooperation.

The cases you cited in your editorial are excellent examples. I doubt that most viewers in the electronics world thought that the AppleIBM/Motorola consortium in particular would succeed with the PowerPC. Too many fingers in the pie, too many ideas, too many superegos to reconcile, and only a short time to accomplish the objectives. The unquestionable success of the program—according to knowledgeable sources—is testimony to the cooperative effort and high expectations of success.

Dave Pryce
Seekonk, MA

(Ed note: Dave Pryce, former *EDN* technical editor, retired from *EDN* in 1993.

Critique on programming criticism

It isn’t often that I write in response to magazine articles, but this time I really felt the need. The *EDN* Special Report “Diagrammatic programming”

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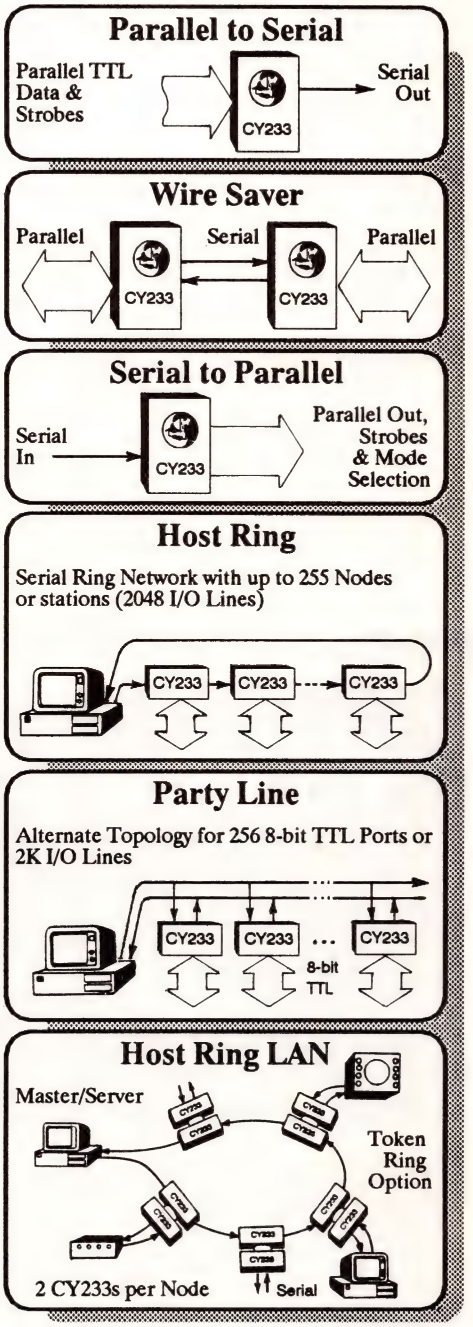

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CIRCLE NO. 37

(January 6, 1994, pg 60) by Charles H Small left something to be desired in regard to the editorial quality I normally associate with articles in your magazine, even when the articles leave your main domain of hardware to dip into software issues.

Small's obvious dislike of doing any text-based programming seriously questions the "facts" he presents in the article, which is unfortunate, because the topic is of interest not only to the intended target audience of hardware design engineers, but also to us programmers. I believe that diagrammatic programming will be the programming method of the future, though it may take some time yet; but the need to enter some code manually, letter-by-letter, will probably never vanish. The "cause" of diagrammatic programming is hardly served by such articles: It is akin to reading an attack on "Wire-'n-Wrap" in *Dr Dobbs Journal.*

Under the guise of objectivity, Small makes it quite clear that programming using textual entry is worth only contempt and somehow makes the connection that "work like an engineer" implies doing entry via some graphic means. I imagine this statement will surprise some 99.9% of individuals claiming to be software engineers. Making the single conclusion that diagrammatic tools are always to be preferred to "hacking away" at "bottomless files" is somewhat naive. There are cases when one or the other is a better choice.

And now for a few additional points:

- "In diagrammatic programming, the ideal is the real; the documentation is the program..." Sure, and "normal humans" can understand this documentation?
- "Diagrammatic programming produces comprehensible software because diagrammatic programming taps the unsurpassed creative and analytical power of the visual hemisphere of the human brain." So which part is used for textual programming? Does this somehow mean that creative programming couldn't be done until diagrammatic programming came along?
- "Dead-code-removal" optimizations that delete complete functions/subroutines are normally performed by the linker, as the compiler works on one file at a time. Also, dead code doesn't always come into existence due to accidents, as Small seems to think; don't forget that such code is often left in *on purpose* by the programmer, eg, in the case of test code (which will probably be needed again...as most programmers with some experience realize).
- As far as I can determine, the diagrammatic tools serve mainly to divide the "lists of unfathomable text" into little parts and thus should mainly be used as a navigational tool or a structure enforcer (forcing the programmer/engineer to think about the code in advance), which can also be achieved through discipline.

It would be interesting to know what kind of errors occur so frequently in large programs so that the error rates are in percentages. It certainly was a nice consideration to "grant the textually minded their view." One of the reasons that software design has to be dif-

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ferent from hardware design is the constant need to adjust the software to hardware bugs/errors (in the real, not the ideal, world) that constantly pop up. Consider prototypes: How often does the hardware engineer resolder those two I/O wires that got mixed up or resolder that buffer to a noninverting one *instead* of asking the software guy to fix it…*You have to change only one line of text, anyway?*

As far as I am concerned, there are several hardware parts that display a behavior that would have been labeled as "bugs" in software (allowing access to registers only once every millisecond, metastability, and frequencies on 5V supply). Another peculiarity of software is the relatively instant availability of fixes, whereas hardware often is plagued by n weeks of delivery time.

The statement "in all the time text-based programmers have been hacking away, they've not been able to accumulate the powerful mixture of art (practice) and science" and that others have merely points out the lack of knowledge Small has in this area. As far as I know, nothing in hardware engineering compares with the gigantic public-domain libraries distributed all over the world (including shareware concepts). As for the accumulating part, it is simple to compare the number and complexity of utilities delivered with a modern operating system with those from 10 years ago. Noting that some software still is full of bugs (where is the complex hardware that is still in use after 30 years?) makes me think of a peculiar property of hardware parts and designs, namely that of inexplicably ceasing to work after a random amount of time.

Instead of filling these pages with comparisons to the biologist's world or brick-building concepts, Small should have been more interested in examining other concepts, such as learning curves, views of real programmers, and possible improvements to project-development times. Somehow, I get the impression that the singular goal of the article was to come down on textual entry itself.

I don't think *EDN* should lend itself to such attacks on the working methods employed by an entire community of professionals. If, however, the intent was simply to publish a provoking article, you succeeded indeed. Apart from this article, keep up the good work.

Lars Thuring
Bad Bramstedt, Germany

Sound off

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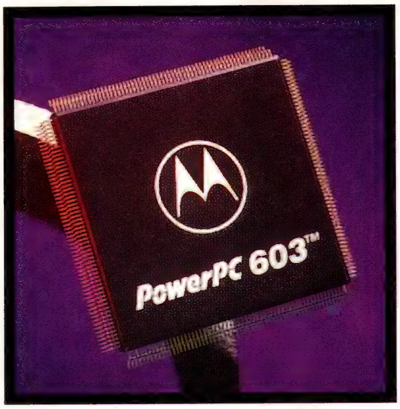

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CIRCLE NO. 36

Reverse-engineering of the third kind

Reverse-engineering of the first kind: Outright copying; theft of intellectual property.

Reverse-engineering of the second kind: For educational purposes; not for recreating an existing product.

Reverse-engineering of the third kind: To take the state of the art beyond its current limits.

We're all familiar with reverse-engineering of the first kind. Copying EPROMs, delidding ICs, and photocopying circuit boards all fall under this category. Some early IBM PC cloners used these techniques to circumvent a lot of development work. As far as I'm concerned, the only reason for practicing reverse-engineering of the first kind is to steal some other company's intellectual property so that you can build the same product and sell it for less. That's not a good reason.

Most of us are familiar with reverse-engineering of the second kind, too. Who hasn't had to reverse-assemble code or look at a schematic to solve a hardware or software interfacing problem or two? Here, we're not trying to copy an existing design; we're trying to create a complementary product. In the past, this practice has been widespread. Today, with the recent court decisions on suits filed between Microsoft and Stac Electronics, this sort of reverse-engineering is on shaky ground, too. Let's hope the courts pour some sanity onto this situation soon.

Recently, I became aware of reverse-engineering of the third kind. The purpose of this practice is to advance the state of the art beyond its current limits. This is the sort of reverse-engineering Steve Gibson did to create SpinRite 3.1, the latest version of his disk-repair and data-recovery software package.

By feeding various data sequences into hard-disk drives and studying the same data when extracted from the drives (with the error-correction protocols switched off), Gibson has been able to determine how the encoders, decoders, AGC amps, and data separators in these drives work. His intent is not to build encoders, decoders, AGC amps, and data separators, but to understand how to make these circuits do more than their designers intended. Using a technique dubbed "flux synthesis," the package applies data patterns to force flux reversals in the disk drive's head-media interface. The net result is to be able to get more precise information about the data stored on the drive, with the hope of safeguarding that data. Consequently, Gibson's white paper "Spinrite 3.1, What's Under The Hood" is a marvelous treatise on how to perform reverse-engineering of the third kind.

Steven H. Leibson

Steven H Leibson
Editor-in-Chief

SpinRite 3.1, $129, Gibson Research Corp, Aliso Viejo, CA. (714) 362-8800; Internet: Steve@GRC.COM.

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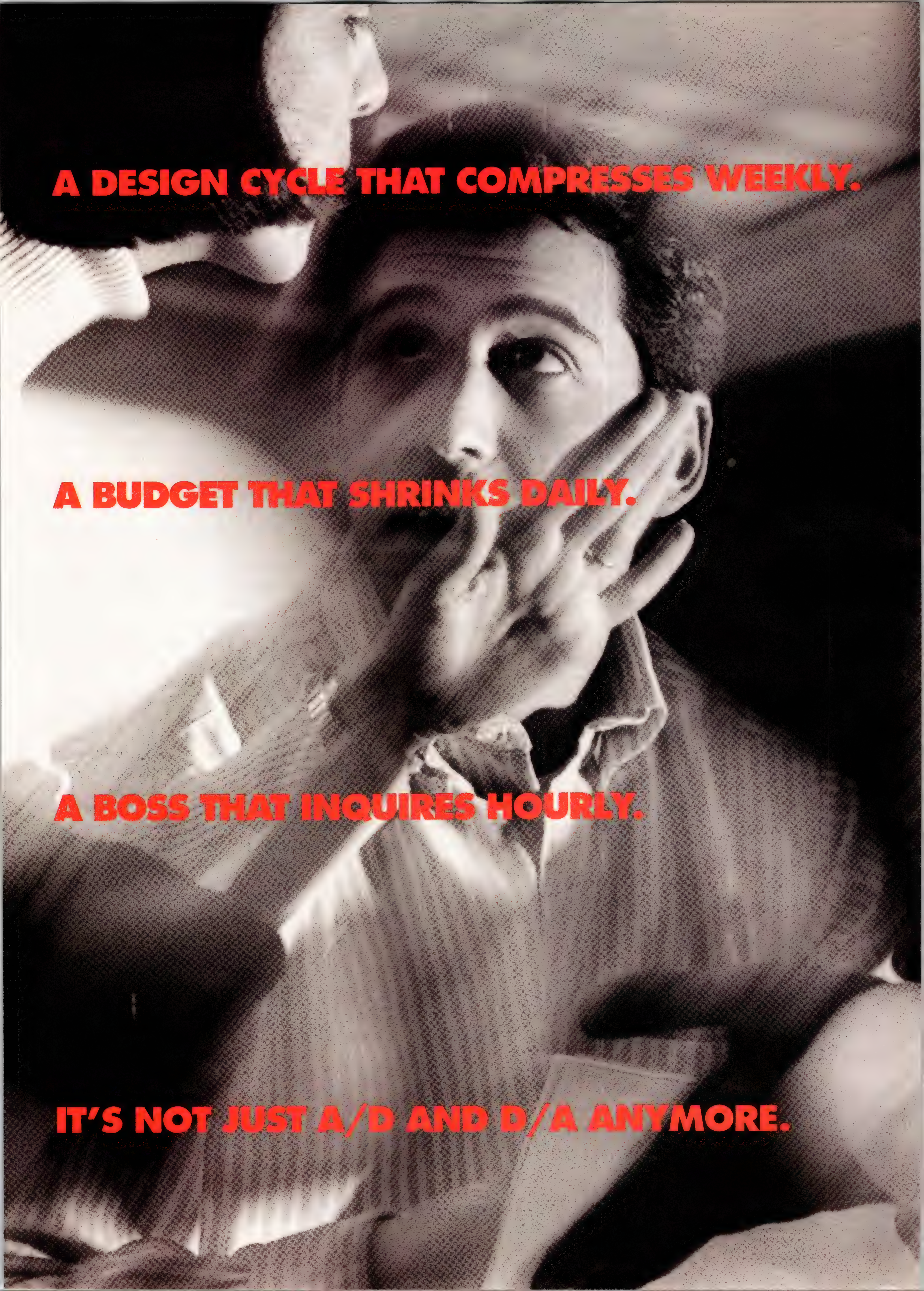
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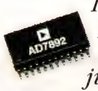

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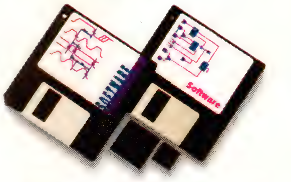

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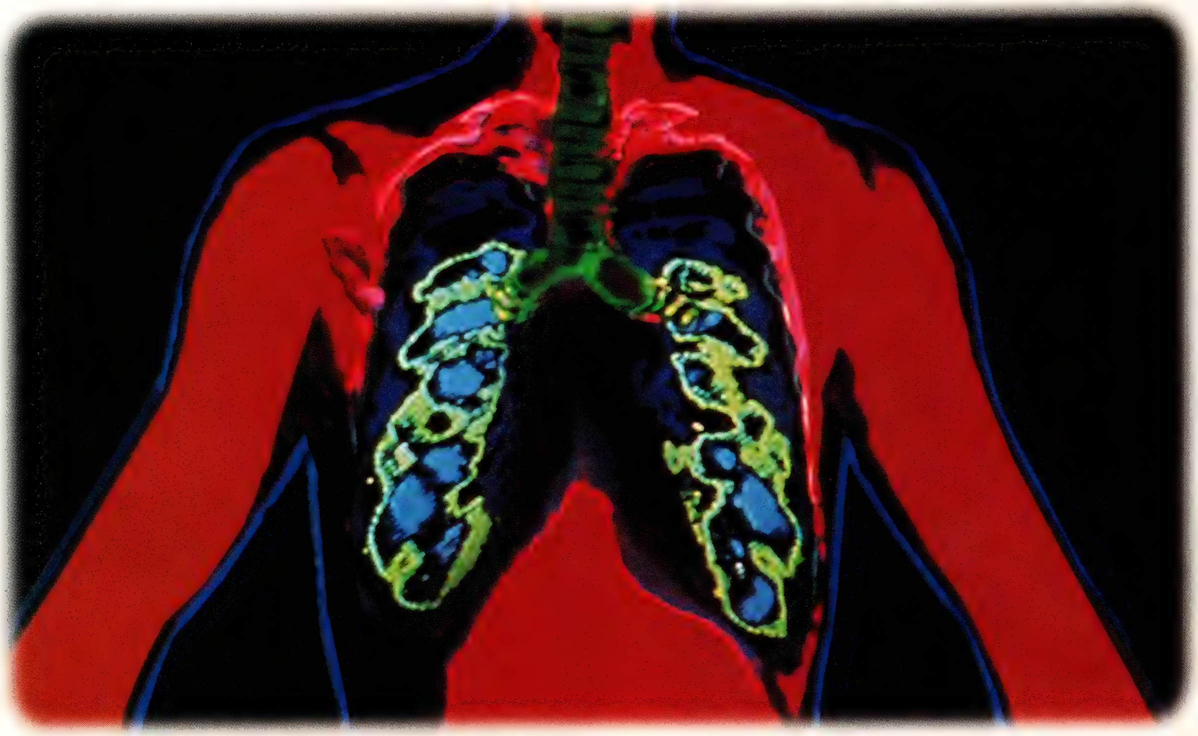

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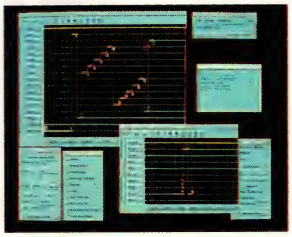

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CIRCLE NO. 87

EDN-TECHNOLOGY UPDATE

Analog HDLs advance speed and enhance modeling flexibility

DOUG CONNER, Technical Editor

Analog HDLs have been commercially available for years, but their acceptance in mainstream analog and mixed-signal design may coincide with an industry-standard language—or two.

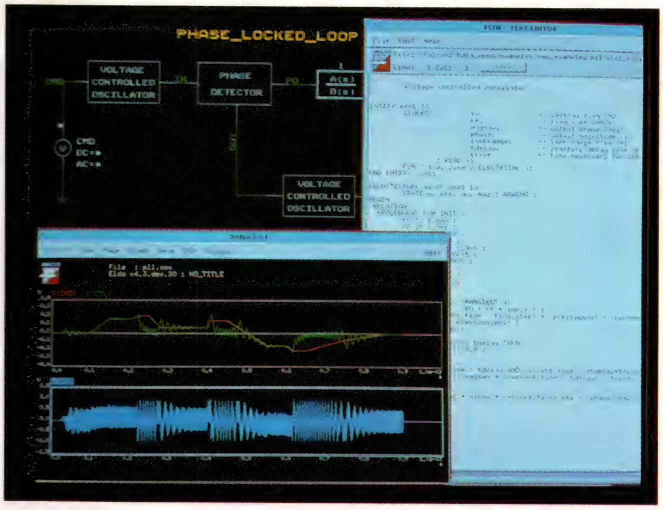
Analog hardware-description languages (HDLs) are not a substitute for Spice butrather another method for specifying and modeling circuits and systems that can be used with Spice. Analog HDLs have the potential to speed circuit simulation, simplify modeling, and provide a better integration of mixed analog-digital simulation.

Most analog-HDL benefits center around modeling. A key difference between Spice and analog HDLs is circuit behavioral modeling. Behavioral modeling is not new: Spice has behavioral models, and a few analog simulation vendors offer analog HDLs (see **Table 1**). Analogy has been selling an analog HDL for years. The primary difference between standard versions of Spice and analog HDLs is that analog HDLs' language definitions contain many more primitives that make creating behavioral models easy and direct.

An analog behavioral model does not try to duplicate every functional element of a system, as would an analog functional model. The behavioral model attempts to model device outputs as a function of its inputs. When modeling devices at the lowest level, there is little difference in speed between a functional model and an analog behavioral model. As you model larger blocks of a design, analog behavioral models begin to show advantages in simulation speed. An op-amp behavioral model can be much simpler than a functional model, where you model each transistor, resistor, and capacitor.

Behavioral modeling is a technique. Inherently, a behavioral model is neither accurate nor inaccurate. You don't build the model up from primitive functions but from overall behavior. You can create models that are just as accurate as Spice; you can even make them more accurate than Spice, especially when characterizing the behavior of actual devices. The accuracy of any model is only as good as you have designed it, whether from Spice primitives or from the larger set of language elements in a behavioral language.

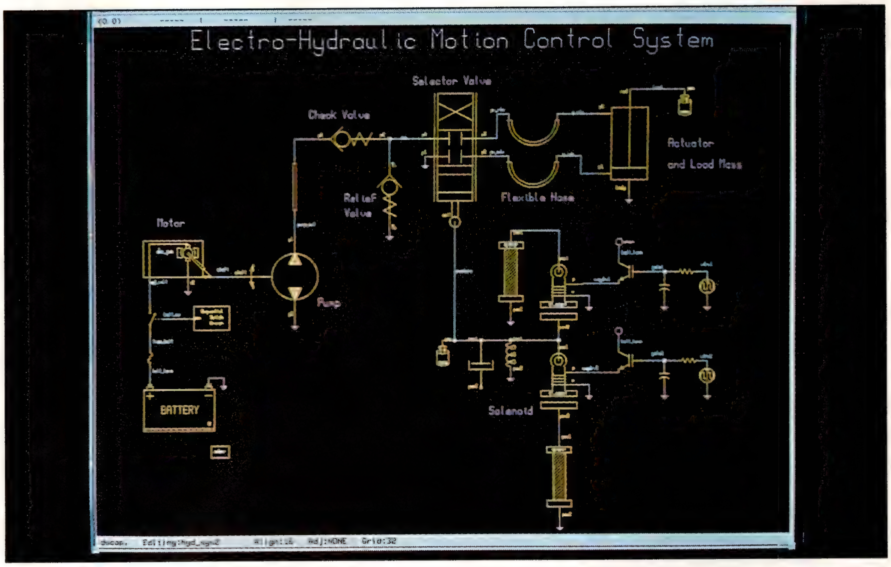
You always need to know a model's limitation. A conventional Spice model may be very accurate for some parameters but not for others. If, for example, you are interested in the temperature coefficient of an op amp's offset voltage, you may find a typical Spice model poorly represents the real device. You can build an accurate behavioral model of the offset voltage vs temperature



HDL-A from Anacad EES is a compiled analog HDL that runs on the company's Eldo simulator. The company plans to keep HDL-A compatible with the VHDL-A standard as it emerges.

coefficient by using behavioral modeling if you know the behavior of the op amp you are simulating.

Behavioral modeling offers a big payoff for those using high-level building blocks. The designer of an op amp needs to know what is going on at the transistor level. An analog designer using the op amp needs only an accurate model of the op amp's input and output behavior. (You don't need to go deeper because you aren't changing the op amp's design.)



Analogy's Mast HDL for analog and mixed-signal designs runs on the company's Saber simulator. Not only can the HDL model analog and digital electrical designs, but the language and available models also let you simulate virtually any system (including mechanical and hydraulic elements shown in the example above).

Simulating large designs

Large analog designs, including mixed analog-digital designs, provide the major driving force toward analog HDLs. In the past, designers created designs at the schematic level. Using Spice models for each element in the design, you could simulate the circuit. Analog HDLs let you design circuits at a higher level. Instead of creating a functional design at the schematic level, you can create the design at a behavioral level and go directly into simulation. The behavioral description is the model for simulation.

Analog HDLs and behavioral modeling encourage you to work with different levels of models. You can use a Spice functional model or an accurate low-level behavioral model for one part of a system and high-level behavioral models for other system parts. This mixed-level simulation approach provides simulation speed for a system design while maintaining high accuracy in a system block you are developing or verifying.

When your task is to design a complex system, you often start by developing a specification for the behavior. You spec what the circuit needs to do before you design the circuit to implement the function. By approaching the design task using a top-down design methodology, you can spec what a system block will do before designing the details for that system block. Behavioral modeling is useful in this case because a functional model doesn't exist until you have developed the design for the system block. A behavioral model can describe the general behavior and let you perform a system simulation to see if the design concept is feasible.

Specifying the design using an analog HDL lets you start with a simple block diagram of a design and add details to it as you refine the design, progressing from concept to implementation. As you begin to implement the design, you can work at the macromodel—and eventually transistor—level, as appropriate for the design.

One significant difference between analog and digital design with HDLs is that you won't be able to access synthesis tools for analog design as you can in digital design. You still have to carry out all the implementation steps. Although the top-down design methodology is more attractive with synthesis tools, it's still useful—even without

ANALOG HDL IN USE

For more than 15 years, American Microsystems Inc (AMI) has been working with customers to create custom analog-IC designs. AMI currently offers its customers what it calls an "MSDS" (mixed-signal design solution). The tool combines Analogy's Saber analog simulator with the CADAT digital simulator. The company's analog library provides parameterized building blocks that let you customize elements by varying the parameters; then the tools generate the device. The company creates the parameterized behavioral models by first carefully characterizing the basic models with Meta-Software's HSpice. The reason for the behavioral model is speed. According to AMI's Bryce Baker, behavioral models run 10 to 100 times faster than the Spice models, with typical designs experiencing approximately 40 times faster simulation.

Occasionally, customers want more detail than is available in stock behavioral models. In that case, AMI finds out what type of information the customer needs and either modifies the behavioral model to provide the information or provides a Spice model of the circuit.

AMI develops the behavioral models using building-block libraries. One of the reasons the company chose Saber was the large model library that already exists. AMI believes an analog-HDL standard will improve the company's situation as well as that of its customers because it is not practical to develop models for more than one simulation language. Customers that would rather use a different simulator cannot do so. A standard would mean customers could use any simulator that meets the standard.

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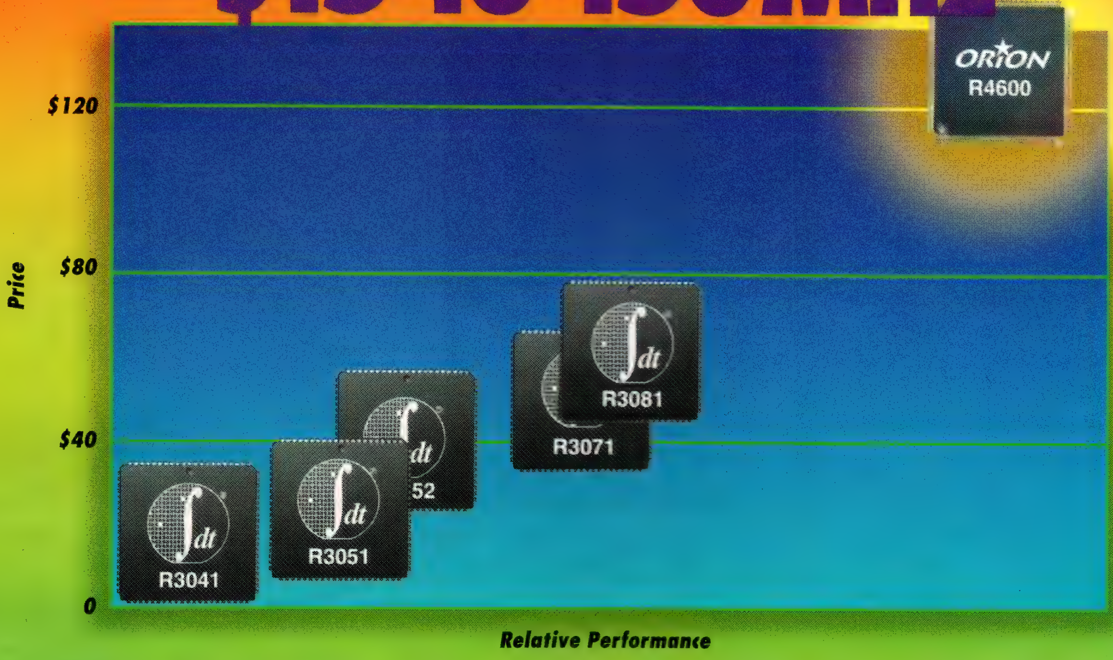

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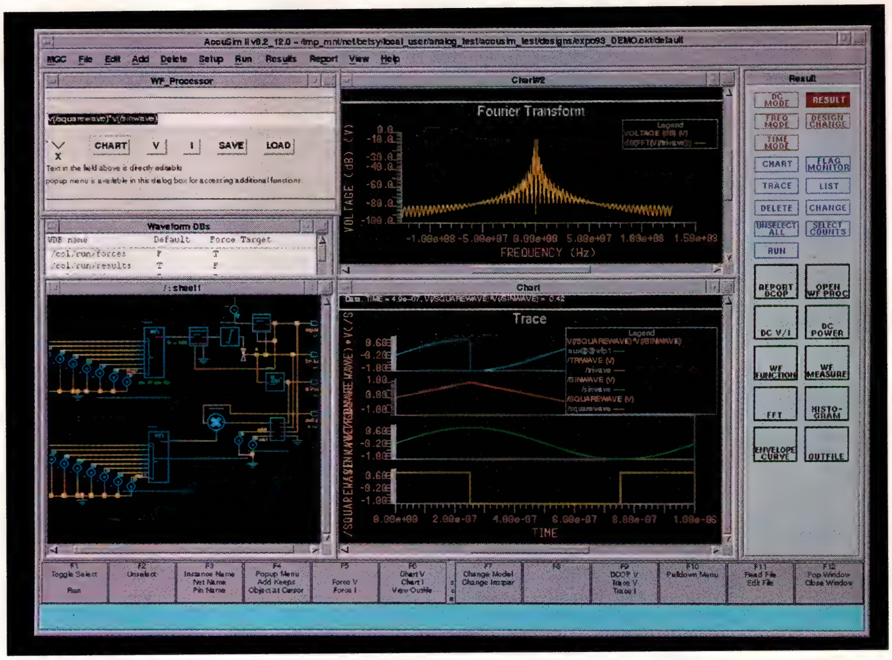
synthesis tools—in bringing large designs smoothly from concept to implementation. The availability of a standard analog HDL also paves the way for eventual analog synthesis tools.

Mixed analog-digital designs

Mixed analog-digital designs are also encouraging the drive toward analog HDLs. Not only are mixed-signal designs usually large, especially IC-level implementations, they often benefit from a tight coupling between analog and digital design and simulation. As HDLs and top-down design methodologies become prevalent for many digital designers, having a complementary design methodology for the analog portion of a mixed-signal design is an important consideration for efficient design.



AccuSim II from Mentor Graphics supports top-down design with high-level modeling. The example shows a function generator simulated at the block level.

Any analog HDL standard that gains most digital designers' approval has to be compatible with VHDL and Verilog. The initial consortium of companies working on an industrywide analog HDL standard settled on VHDL as the working digital standard. The VHDL-Analog (or simply VHDL-A) effort expects to produce a language reference manual (LRM) by the end of 1994 or in early 1995. The group plans to work toward IEEE approval of the standard.

Even before the VHDL-A standard is done, Cadence is pushing an effort toward a Verilog-A standard to support its large base of Verilog users. Although a second analog behavioral language for Verilog destroys the hope for a single analog HDL to support, the situation may not be quite as bad as it first appears. Cadence is a strong supporter of both VHDL-A and Verilog-A. Although the company views developing two standards as creating more work, it believes model interoperability is possible, which eases the problem for both end users and companies developing models for devices.

Why not just tweak Spice?

With the effort toward an analog HDL, both designers and Spice-tool vendors share a bit of skepticism. The analog-simulation companies probably have a greater concern about a good standard than even end users do. As a user, if you don't like the language standard, you don't use it. Simulation-tool companies are compelled to sink resources into supporting a new standard if it appears to be at all commercially feasible.

When Wolfram Blume, president of MicroSim, says "There is no room for a poor analog HDL standard," he's focusing on the concerns of many analog-simulation companies. The analog-simulation world has Spice, which is and will contin-

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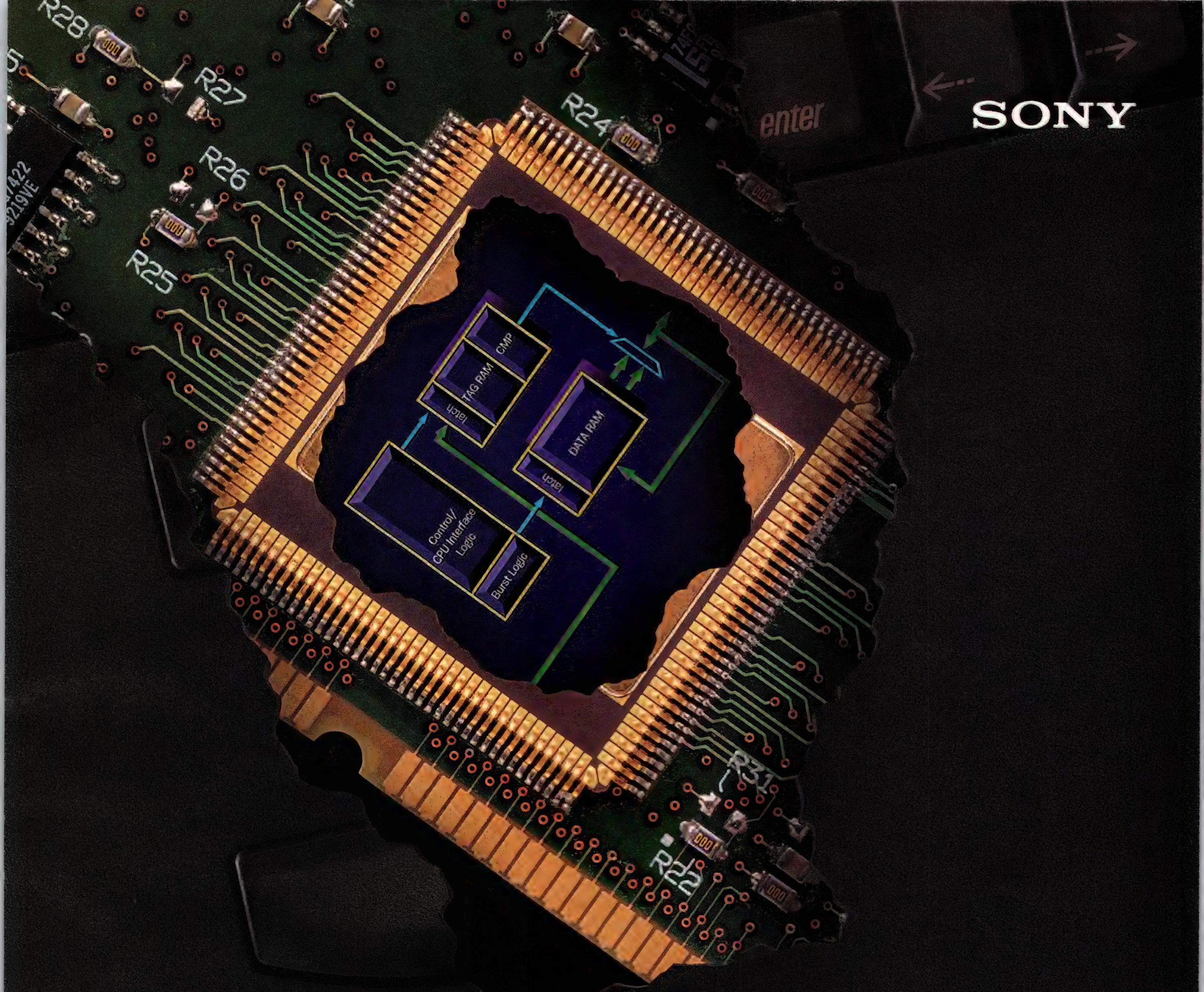

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ue to be an important industry standard. If the VHDL-A standard is to succeed, it must be a good standard because users will never adopt a mediocre standard while Spice is still viable.

So what's standing in the way of a more evolutionary approach to modifying Spice to add the HDL capability?

Spice macromodels have been used successfully for some time in creating faster simulating models of op amps and other analog building blocks. The largest obstacle to improving simulation speed with Spice macromodels is probably the limited set of primitives available. To relieve this problem, just about every vendor of Spice tools has added proprietary-language extensions to improve behavioral modeling. The new embellishments can often become a liability to end users. As soon as you take advantage of proprietary features, you start to lose model portability. Because models are so important, the model-portability problem is always high on the list of concerns for simulation users.

Companies such as Analog Devices, which provide Spice models for many of the ICs they develop, have to decide which primitives to use in modeling their devices. To make the models useful to the widest audience, the company has to adhere to the most generic Spice standards.

The analog HDL efforts, VHDL-A and Verilog-A, are an attempt to transcend the slow evolution of Spice and to establish industrywide standards, so that analog designers and analog-design tool suppliers can more quickly reap the benefits of an analog HDL industry standard. The effort is not without risk. Rubber-stamping a successful de-facto industry standard is much safer than trying to create a language that will become a successful industry standard.

GET INVOLVED WITH THE VHDL-A STANDARD

To make the VHDL-A standard successful, AVI (Analog VHDL International), the industry consortium working on VHDL-A, needs more practicing analog-circuit designers to participate. If you're interested, contact Shawn Hailey, secretary of AVI, at (408) 369-5400.

The bottom line is that Spice will require a lot of additions to build the set of primitives to adequately cover what is needed for analog behavioral modeling. Whether you end up calling those additions VHDL-A, Verilog-A, or modified Spice, the additions are significant.

At the same time, it's important to remember that the analog HDLs must be fully compatible with Spice. For the most part, simulation-tool vendors will continue to use their Spice simulators, and analog HDL will be an additional capability.

Graphical modeling

An additional concern for some analog designers is having to create all those HDL models. To start with, you can use any Spice model you currently have. You won't get the faster simulation benefits of a behavioral model, but you won't lose any models you already have. Second, if you see your digital counterparts sweating over what appears to be reams of software code cleverly disguised as VHDL, you probably think there has to be a better way. And there is.

You should be able to use graphical building blocks and templates to create your models and system designs. Most simulation companies plan to offer these features to make it easy for designers to become proficient using an analog HDL—without having to learn details of the language.

The language reference manuals that will define VHDL-A and Verilog-A won't specify graphical representations, which will be strictly proprietary developments. Because the models will use the underlying analog HDL, they will be interchangeable, even though the graphic representation will not.

Contact Technical Editor Doug Conner at (805) 461-9669, fax, (805) 461-9640.

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TABLE 1—REPRESENTATIVE ANALOG SIMULATORS WITH ANALOG HDL CAPABILITY

Manufacturer	Product	Description	Accepts Spice models	Analog HDL	Mixed-signal capability	Price
Anacad **Circle No. 302**	Eldo	Multilevel analog simulator	Yes	HDL-A	Yes	$22,000
	HDL-A	VHDL-based analog behavioral language	N/A	Yes	N/A	$8000
Analogy **Circle No. 303**	Saber	Simulator for analog and mixed-signal simulation	Yes	MAST	Yes	$20,000
Dolphin Integration **Circle No. 305**	Smash	Simulator for analog and mixed-signal simulation	Yes	Yes	Yes	$5600
Mentor Graphics **Circle No. 306**	AccuSim II	Multilevel analog simulator	Yes	HDL-A	Yes	$25,900

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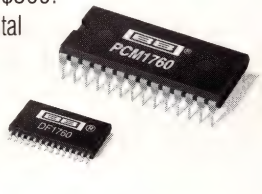

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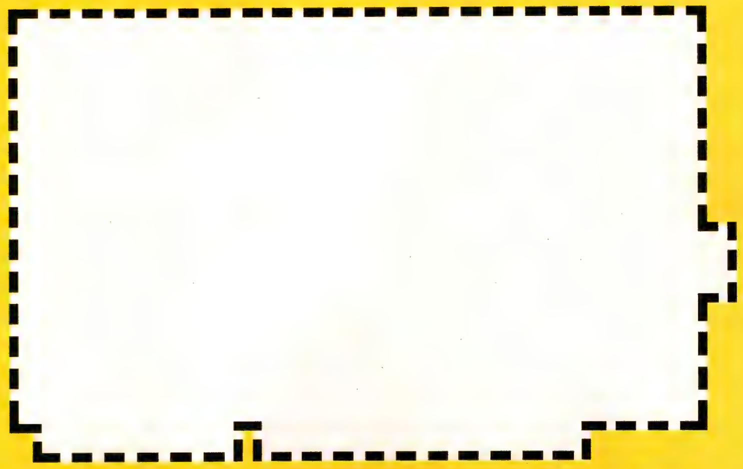

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Gary Legg, Senior Technical Editor

Thanks largely to easy-to-use design tools, fuzzy logic is now gaining a foothold in embedded systems. Although large numbers of commercial fuzzy-logic applications have yet to materialize (especially in the US), numerous successful test projects indicate that many fuzzy products will soon follow. For the most part, product developers will implement these products in surprisingly compact code in conventional microcontrollers (μCs).

Fuzzy logic is slowly catching on, and fuzzy design tools are getting better: They don't just help design fuzzy logic, they let you create complete embedded systems.

Real commercial applications, however, require that fuzzy tools do more than just aid the design process. Because fuzzy code almost always coexists with conventional code in embedded systems, fuzzy tools must help combine the two. Increasingly, the tools are doing just that.

Better system capabilities

The latest fuzzy-logic tools provide substantial improvements in system-development capabilities. Intel's Fuzzybuilder, for example, merges fuzzy tools with Apbuilder, a software tool that automatically generates peripheral-initialization code for MCU-96 μCs. Also included is Modelbuilder, a software package that lets you create a system-level application model without writing any code. The fuzzy part of Fuzzybuilder comes from Inform, which also supplies a remote real-time debugger for fuzzy applications. Similarly, Togai InfraLogic includes remote debugging in its tools' capabilities.

Fuzzy tools are also linking with other tools: some fuzzy, some not. For example, Fuzzy Systems Engineering's Fuzzy Knowledge Builder (previously Manifold Graphics Editor) now creates input to ByteCraft's Fuzz-C Preprocessor, thus linking a front-end fuzzy design tool to a C-like language that appeals to designers already versed in conventional system development. For Windows-based applications, HyperLogic's CubiCalc and some other fuzzy tools now link fuzzy programs to other programs via dynamic data exchange (DDE).

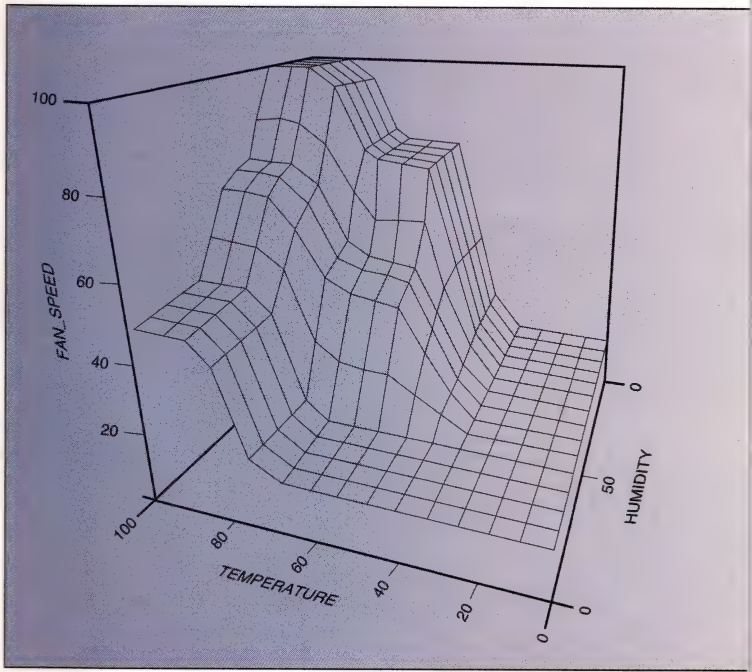

Fig 1—Simulators in fuzzy-logic tools can draw control-surface plots to show system response. Byte Dynamics' Fuzzy Logic Designer drew this plot.

Because the adaptation of fuzzy logic has been slower than expected, some fuzzy-tool manufacturers are scrambling to survive. As a result, choosing the right fuzzy tools to use—difficult enough in itself—can be complicated by concerns over whether or not a tool provider will remain viable.

Companies suffering most from the sluggish pace of fuzzy logic's commercial proliferation are those that have concentrated solely on fuzzy-logic products. Togai InfraLogic, Aptronix, and NeuraLogix, for example, have all put a great deal of effort into fuzzy products that have been slow to take off. As a result, Togai has scaled back, Aptronix has branched into fuzzy-logic consulting, and NeuraLogix has relocated from Florida to California's Silicon Valley. Of all the companies concentrating exclusively on fuzzy-logic tools, only pioneer HyperLogic has remained healthy. Other companies with fuzzy tools either augment their income with consulting and training in fuzzy logic or have developed fuzzy tools as an outgrowth of regular business.

Semiconductor partnerships

Semiconductor companies with a stake in fuzzy logic—notably companies that manufacture μCs—have formed relationships with third-party tool vendors. Inform, a German company that has offices in the US, is the most prominent of the third parties, having established partnerships with Intel, SGS-Thomson, Siemens, Texas Instruments (for fuzzy DSP applications), and Microchip Technologies. Chip-maker Hitachi has a partnership with Togai, as does VLSI Technology. Motorola works with Togai, Aptronix, and Hiware and also has in-house tool development. Of all the major chip makers, only National Semiconductor has developed its fuzzy tools solo.

Europe and Japan are well ahead of the US in fuzzy applications, and Europe, not surprisingly, is a major source of fuzzy design tools. Inform is the best known of the fuzzy companies, but Switzerland's Hiware is now getting attention from its alliance with Motorola. Another Swiss company, Fuzzysoft, also develops fuzzy tools; it markets through GTS Trautzl GmbH of Germany. Together, European and American fuzzy-tool vendors add up to a sizable number (**Table 1**).

Even some enthusiastic developers of fuzzy applications have been slow to adopt fuzzy tools, however. You can get by without special tools, they report, because fuzzy-logic software isn't all that complicated (**Ref 1**). Typical fuzzy controllers often run in only a few hundred bytes of code.

But to ignore the benefits of fuzzy tools, say other developers, is to ignore the benefits of fuzzy logic itself. Fast prototyping is one of fuzzy logic's main strengths, according to fuzzy-design-consultant David Brubaker, and prototyping is where fuzzy tools work best. Tools that can simulate a fuzzy design's performance are especially useful, says Brubaker. The simulator in HyperLogic's CubiCalc often assists Brubaker in quick feasibility studies, which turn into actual design projects.

Multiple capabilities

Various fuzzy design tools provide one or more of several capabilities:

- Help to design a fuzzy control system with CASE (computer-aided software-engineering) capabilities
- Simulate a fuzzy design to help validate it, as previously mentioned
- Generate code, in C or in various assembly languages, for implementing a fuzzy design
- Help to merge the fuzzy code with other code
- Help debug the entire system.

Using fuzzy tools to design a fuzzy controller requires knowing how fuzzy logic works (**Refs 2** to **5**). Essentially, says Brubaker, you have to learn how to work in a different domain. Fortunately, that domain offers advantages that make your effort to learn worthwhile.

Different tools support the various fuzzy design steps in a range of ways—and to varying degrees. At a minimum, however, all tools let you do three things: define fuzzy input and output

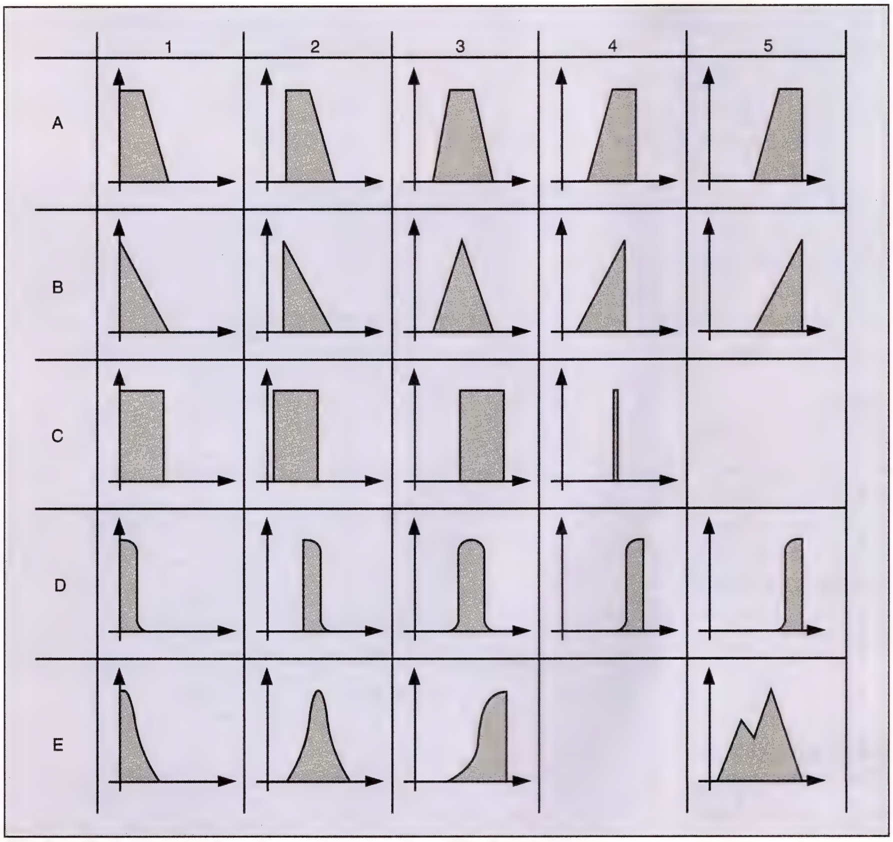

Fig 2—Membership functions take a variety of shapes, as this selection screen from GTS Trautzl's FS-Fuzzysoft shows. The most commonly used functions are triangular and trapezoidal.

variables; specify fuzzy sets (also called membership functions or adjectives) that correlate fuzzy variables with fuzzy values; and define linguistic rules that describe the desired system behavior.

Once you have a fuzzy design, most of the tools automatically generate code for implementing it. Usually, the code is in C or assembly language for one of a number of µCs. A few tools do provide other languages, however (see **box**, "Features to look for"), including Basic, Fortran, and Ada. Often, fuzzy-tool-generated source code contains clear explanatory comments about the fuzzy operations it implements.

Tuning with a simulator

A simulator helps you "tune" your fuzzy design. Tuning, an iterative process of refining a fuzzy design, is usually the most time-consuming part of creating a fuzzy system. Without simulation, you can get into a lengthy loop of design modifications, code generation, downloading, and debugging. With simulation, you see the results of design changes almost immediately.

Simulators provide displays that demonstrate system behavior. These displays include both 3D plots of control surfaces (also called decision surfaces) and 2D orthogonal slices through the control surfaces. The 3D plots usually show one output variable as a function of two input variables (**Fig 1**); alternatively, they may show an error term as a function of inputs. Many simulators let you alter plot perspective by changing your apparent vantage point. To help compare the results of changes on different output variables, some simulators also let you view multiple 3D windows simultaneously.

With some tools, you can make design changes on the fly in the tuning process and see their simulated effects immediately. Typical modifications include changing the shapes of fuzzy membership functions, changing the values of variables, and defining new plots. You can usually change rules, too, although some restrictions may apply. For example, with some tools, you may have to restart the simulator when you change rules. With Togai's simulator, you can always delete and disable rules on the fly, but you'll have to make provisions when you set up your system if you want the option to add rules.

Remote, real-time debuggers help wring out a fuzzy controller after it's running in a target system. Like simulators, real-time debuggers let you alter, add, or delete membership functions and rules. Unlike simulators, these debuggers provide feedback from the embedded system itself. A communications link exists, usually via an RS-232C port, between the host and target systems. Remote debuggers are available from Inform and Togai.

Features for fuzzy design

At the heart of most fuzzy tools is the capability for creating the design for a fuzzy control system. With features such as graphics-based function editors and linguistic fuzzy-rule editors, the tools let you work intuitively in the fuzzy domain, at a level of abstraction above that of ordinary programming.

You begin a fuzzy design by specifying input and output variables and by defining membership functions. Membership functions typically have names like "warm" (to describe, for example, a measured temperature) or "fast." They express the fuzzy designer's intuitive concept of which temperatures correspond to "warm" and which speeds are fast. Depending on the fuzzy tool, you can create membership functions with a graphics editor, a text editor, or both.

Membership functions can have many different shapes (**Fig 2**), although not all fuzzy tools support all shapes. The most common shapes are triangles (pyramids) and trapezoids (truncated pyramids), which are usually symmetrical, but don't have to be. Membership functions can have many other shapes and even can be nonlinear, although nonlinear functions usually get converted to piecewise linear approximations when implemented in µCs. Output membership functions (sometimes called consequence functions) can also include singletons, which denote fixed values.

Simple membership functions, such as those with triangular and trapezoidal shapes, are adequate for most applications. In most cases, the smoothness of system response depends more on function overlap and defuzzification technique than on function shape. Really complex applications may require more complex shapes and, most likely, additional computing power—a 16-bit controller instead of an 8-bit device, for example. Nonlinear membership functions are usually confined to workstations, says Brubaker. For µC implementations, storage and computational costs are prohibitive.

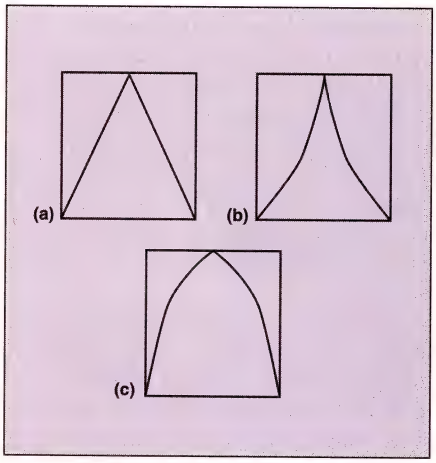

Fig 3—Hedges modify membership functions. Modifying an original triangular function (a) by the hedge "very" yields (b); modification by the hedge "somewhat" yields (c).

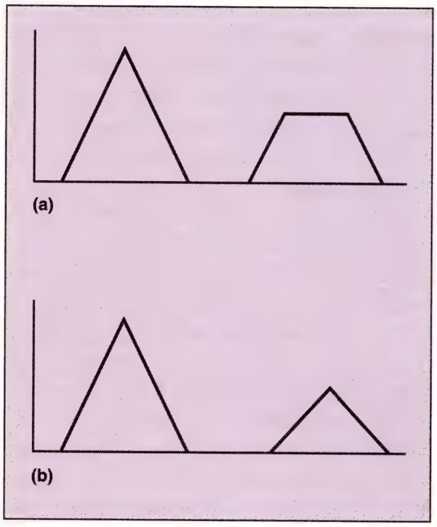

Fig 4—Applying a rule-activation level to output membership functions results in two types of scaling: by minimum (a), which truncates the function, and by multiplication (b), which retains its general shape.

Functions on functions

Some fuzzy design tools let you modify membership functions with "hedges" to accentuate or diminish the functions' effects. For example, the hedge "very" intensifies a function's effect; the hedge "somewhat" diminishes it (**Fig 3**). Different tools implement hedges in different ways. Typically, an intensifier such as "very" results from a pointwise squaring of the modified adjective; a diminisher such as "somewhat" results from a pointwise square root.

The utility of hedges is akin to the utility of subroutines. For example, instead of implementing several separate membership functions, you can save code by applying different hedges to a single function. Also, like subroutines, hedges aid conceptual understanding. Essentially, they apply a function to a function.

To help you define the rules for controlling a fuzzy system, fuzzy tools provide rule editors. These editors let you express rules linguistically with "if-then" statements. Some tools also provide matrix rule entry, which simplifies rule input (you don't actually need to write "if" and "then") and promotes thoroughness.

Fuzzy rules may have single or multiple antecedents ("if" parts) and consequents ("then" parts). Rule operators separate multiple antecedents. Virtually all tools provide an AND operator (for statements such as "if temperature is warm AND humidity is high"); other tools may have additional operators such as OR and NOT. Some tools also allow parentheses to control the order of term evaluation. The more flexibility a tool offers in writing rules, the more you can express rules in the way you naturally think. (Do not assume, however, that having fewer rules with more terms is better. Sometimes, reducing the number of rules is more trouble than it's worth.)

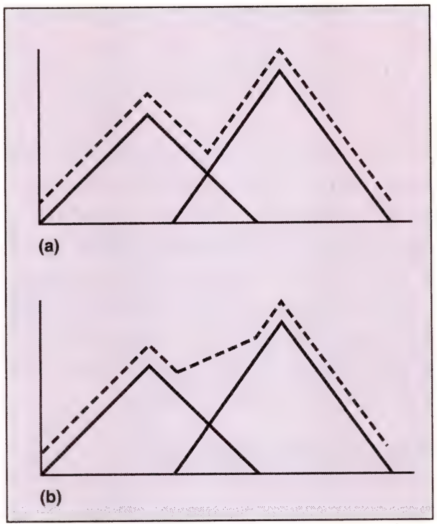

Fig 5—Combining a rule's output-membership functions shows the rule's overall effect. The combined result can be the maximum points of the two functions (a) or the sum (b).

What the fuzzy code does

The code a fuzzy tool generates must perform all the steps required of a fuzzy-logic controller. These steps include fuzzification (to convert input "crisp" values to fuzzy values), inferencing (application of fuzzy rules), and defuzzification (to determine crisp output values). Different tools perform the steps in different ways, and some individual tools provide choices of methods for some steps.

Fuzzification determines membership degrees (from 0 to 1) of input variables in fuzzy sets, which are denoted by input membership functions (partial membership is permissible in fuzzy set theory). For a simple single-antecedent rule, the degree of membership determines the degree to which the rule is active or the degree to which the rule's specified output actions occur. The methods the fuzzy tools provide for determining degree of membership range from simple table look-up to interpolation to computation of nonlinear functions. Obviously, the different methods make different demands on a fuzzy system for memory and computational power.

For multiple-antecedent rules, fuzzy inferencing combines the effects of all antecedents to determine a rule's overall effect. For two antecedents separated by an AND operator, the result most fuzzy tools supply is the minimum of the antecedents' degrees of membership in their respective fuzzy sets. For antecedents separated by an OR operator, the result is usually the maximum of the two numbers. Some tools (FS-Fuzzysoft, for example) provide more than simple minimum and maximum choices, but using this type of tool is probably beyond a novice designer's capabilities.

A rule's activation level, determined by combining antecedents' effects, applies to the rule's output membership function(s) to determine how much the rule contributes to system behavior. (In simple terms, the degree of truth of a rule's "if" part determines the degree

LOOKING AHEAD

One advantage fuzzy logic has over conventional control systems is its flexibility in accommodating fairly broad variations in system parameters. In the future, however, fuzzy logic will be even more flexible. The components of a fuzzy system will be variable—rather than fixed—so the system itself can change as conditions change.

In adaptive fuzzy-logic systems, rules and fuzzy sets (membership functions) can change on the fly. Some fuzzy design tools may add support for adaptive systems as early as this year, although many fuzzy designers may not be ready yet for that next level of abstraction.

Although many designers still are learning how to use fuzzy logic's most basic capabilities, the long-range trend will be toward creating more sophisticated systems. For example, fuzzy-logic consultant David Brubaker reports already having designed a system with two fuzzy controllers—one that actually provides system control and another that adapts the first one to changing conditions. The combination of fuzzy control and conventional proportional-integral-differential (PID) control will also be more prevalent. An adaptive system could even use a fuzzy controller to adapt a PID controller to changing conditions. Eventually, genetic algorithms will help fuzzy systems adapt.

In the meantime, the use of neural networks with fuzzy systems will grow. And that growth will be assisted by more and better fuzzy design tools with neural-net modules.

of application of the rule's specified output actions.)

Application of the rule activation level to the output membership function most often occurs in one of two ways (**Fig 4**): clipping (sometimes called scaling via minimum) or scaling (also called scaling via multiplication). If your fuzzy tool provides a choice, determining which scheme to use can depend on your having a good working knowledge of fuzzy logic. However, some tools that offer both schemes help you make a choice according to the type of application you're designing. HyperLogic's CubiCalc, for example, defaults to the multiplicative scaling option if you've specified that the system you're designing should have a smooth response. Alternatively, the purpose of some fuzzy systems is to make distinct choices, in which case the response should not necessarily be smooth.

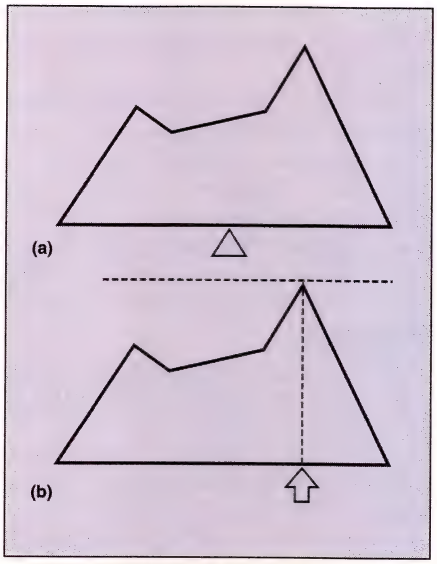

Fig 6—Defuzzification converts combined output-membership functions to a single real value. Two common methods select output values from a centroid (a) and the point of maximum height (b).

Schemes for combining rules

To determine the combined effects of all rules, fuzzy inferencing combines output fuzzy sets (consequents) to create a resultant fuzzy set. Again, various combination schemes exist; CubiCalc's options (**Fig 5**) illustrate the general idea. In **Fig 5**, the combination of two sets may result in the maximum point-by-point values of the two sets, the added pointwise values, or simply the "best" of the two sets. In general, "max" and "sum" tend to be better for continuous response, and "best" is better for distinct choices. The CubiCalc user's manual offers more detail.

Ultimately, the process of defuzzification computes a "crisp," numerical output value from scaled and combined membership functions. This process, like others, can occur in a variety of ways (**Fig 6**). One method, usually called the centroid method, computes the center of gravity of combined, scaled-output membership functions. Other methods include variations that involve the maximum height of the resultant consequent. As with other stages of the fuzzy process, the preferred method sometimes depends on whether you need smooth results or whether you are selecting from discrete choices. The centroid is good for smooth results but somewhat compute intensive.

Knowing which fuzzy options to use, or even which ones to require in a fuzzy design tool that you buy, depends on a level of knowledge too great for an article of this length to convey. However, it's often true that fuzzy logic's robustness enables you to create a very good controller even if you haven't made all the best possible choices. Most important, according to many fuzzy designers, is simply to get started in fuzzy logic. Experience is the best teacher.

You can learn fuzzy logic in different ways. Most fuzzy-tool vendors have inexpensive, limited-capability versions of their products, which you can learn to use hands-on. Some of the tools' user's manuals also contain good

FEATURES TO LOOK FOR

Unless you're ahead of most others on the learning curve, you probably won't need fuzzy-logic design tools with the most exotic features. Your primary concern, in fact, might simply be what processors the generated fuzzy code will run on.

Most fuzzy tools are available in versions for generating assembly-language code for numerous μCs. Other tools produce code for Texas Instruments TMS320 DSPs and for fuzzy processors and coprocessors from VLSI Technology and NeuraLogix. Most tools also generate C code.

In addition to C, some tools produce code in other high-level languages. Fuzzle, from Modico, generates Fortran; Fuzzy Knowledge Builder, from Fuzzy Systems Engineering, generates both Fortran and Basic. RT/Fuzzy Module, part of a larger system-development package from Integrated Systems, produces C and Ada code. The Fuzz-C Preprocessor from ByteCraft lets you write in a C-like language created just for fuzzy systems.

A simulator is an especially good feature to have in a fuzzy tool. Simulators are available in many tools; some others can link to separate simulators, such as MatLab.

A matrix rule editor is also nice. Implemented first by Fuzzy Systems Engineering, this feature is now in several other tools. A matrix editor simplifies rule entry and promotes thoroughness by displaying your entire rule base in tabular form.

A graphical membership-function editor can be helpful, although sometimes a text editor is more convenient. Try to select a tool with both—and then take your pick.

Membership functions more complex than triangles and trapezoids may go unused until you're a fuzzy expert, but they do reflect a tool's sophistication. Similarly, hedges are for the well initiated.

A remote real-time debugger will appeal to engineers with embedded-system experience. Unlike simulators, real-time debuggers let you know what's happening in the processor that runs your fuzzy code.

The control-systems specialist may benefit from FS-Fuzzysoft (GTS Trautzl), which allows mixing of classical and fuzzy techniques.

tutorial information, and many fuzzy tool companies offer training in fuzzy-logic design.

Automation via neural nets

You may be able to bypass some learning by using a tool with neural-network capabilities. The neural nets in these products can "learn" how a system should work by processing large numbers of input and output data sets. With that knowledge, the tools then generate the code for a fuzzy system with much less user involvement than would otherwise be required. Neural-net tools for fuzzy applications are available from Inform, Motorola, National Semiconductor, and Togai. National recently updated its offering to produce C code; the earlier version generated only assembly code for COP8 controllers.

If neural nets spare you the effort of learning fuzzy logic, however, they may exact a price in demanding at least a rudimentary knowledge of neural networks. They can also require large amounts of computing time to do their learning.

As with every new discipline, fuzzy logic has a learning curve. It's not a terribly steep curve, though, according to many fuzzy designers; it just requires putting in the time and effort to shift into a new mindset. Most designers who have made the effort say it's worth it. EDN

References

1. Legg, Gary, "Transmission's fuzzy logic keeps you on track," *EDN*, December 23, 1993, pg 60.
2. Brubaker, David, "Fuzzy-logic basics: intuitive rules replace complex math," *EDN*, June 18, 1992, pg 111.
3. Brubaker, David, "Fuzzy-logic system solves control problem," *EDN*, June 18, 1992, pg 121.
4. Legg, Gary, "Special tools and chips make fuzzy logic simple," *EDN*, July 6, 1992, pg 68.
5. Conner, Doug, "Designing a fuzzy-logic control system," *EDN*, March 31, 1993, pg 76.

Acknowledgments

Dr David Brubaker of Huntington Advanced Technology (Menlo Park, CA, (415) 325-7554) provided useful comments, suggestions, and information for this article. David's fuzzy-logic column premieres in this issue of EDN and will appear every other issue.

Special thanks to HyperLogic (Escondido, CA, (619) 746-2765) for illustrations and concept explanations from the CubiCalc user's manual. The CubiCalc manual is a good source of information about fuzzy-logic design.

Contact Senior Technical Editor Gary Legg at (617) 558-4404; fax (617) 558-4470.

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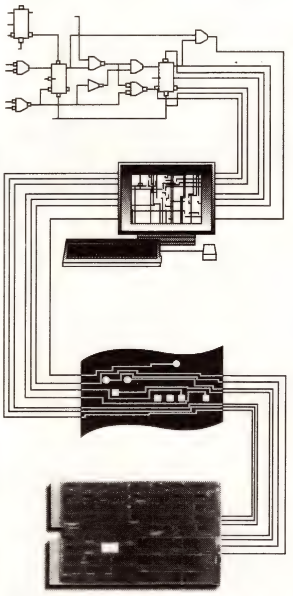

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TABLE 1—FUZZY-LOGIC TOOLS

Source	Product	Description	Price
Aptronix Inc San Jose, CA (408) 428-1881 **Circle No. 350**	Fide high-level kit	Windows-based graphical tool has matrix rule entry and simulator. Develops C code, MatLab M file code, and assembly code for Motorola 6805, 68HC05, 68HC08, 68HC16, and 6833x.	$3495
	Fide midlevel kit	Same as high-level kit, but generates only C code and assembly code for 6805, 68HC05, 68HC08, and 68HC11.	$1995
	Fide starter kit	Limited-capability version. Generates C code and 68HC11 assembly code.	$350
ByteCraft Ltd Waterloo, ON, Canada (519) 888-6911 **Circle No. 351**	Fuzz-C Preprocessor	DOS-based tool translates C-like fuzzy-logic descriptive text to fast, compact C source code. Shows simple plots of membership functions as comments within the code.	$149
Byte Dynamics Spokane, WA (509) 926-6011 **Circle No. 352**	Fuzzy Logic Designer	Windows-based graphical tool develops ANSI C source code. Simulator provides 3D and 2D plots.	$395
Fuzzy Systems Engineering Poway, CA (619) 748-7384 **Circle No. 353**	Fuzzy Knowledge Builder	Windows-based tool provides matrix rule entry and graphical input of membership functions. Simulator provides 3D and 2D plots. Creates code in C, Basic, Fortran, and assembly languages for processors from Motorola, National, TI, Intel, and Analog Devices. Also creates ByteCraft Fuzz-C Preprocessor code.	$295
	Fuzzy Thought Amplifier	Windows-based tool provides interface for modeling, capturing, and exercising thought models. Provides graphical input in format of directed graph with feedback.	$129
	Fuzzy Decision Maker	Windows-based tool helps break apart and capture subjective judgments needed to make complex decisions.	$195
GTS Trautzl GmbH Kaltenkirchen, Germany Fax (49) 4191-88665 **Circle No. 354**	FS-Fuzzysoft	Windows-based tool that adds fuzzy logic to system-design and conventional control (P, PI, PID) capabilities. Has matrix rule editor and simulator. Optional modules generate C code and assembly code for 68xxx, 8051, 6811, and 80C166. FS-Fuzzy-expert NFS option adds neural-net capability.	$499
Hitachi America Ltd Brisbane, CA (415) 589-8300 **Circle No. 355**	Fuzzy Logic Embedded Controller Development Packages	Windows-based tools developed with Togai generates assembly-language code for H8/300, H8/500, HMCS400, and SH (32-bit RISC) controllers.	$1530 to $4500
Hiware AG Basel, Switzerland (41) 61-3317151 **Circle No. 356**	Hi-Flex	Windows-based graphical tool generates C code and assembly code for 68HC11 now, more Motorola microcontrollers later. Includes simulator and debugger. Allows use of nonfuzzy functions.	N/A
HyperLogic Corp Escondido, CA (619) 746-2765 **Circle No. 357**	CubiCalc	Windows-based graphical tool for developing PC-based fuzzy logic. Has extensive simulation, tracing, and plotting capabilities.	$495
	CubiCalc-RTC	CubiCalc superset converts fuzzy systems into C structures for use with included DLL or in stand-alone 80x86 programs. Optional fuzzy-engine source code allows embedded-system development. Optional CubiCard ($700) gives PC analog and digital I/O.	$795
	CubiQuick	Limited version of CubiCalc allows experimenting with fuzzy logic.	$179

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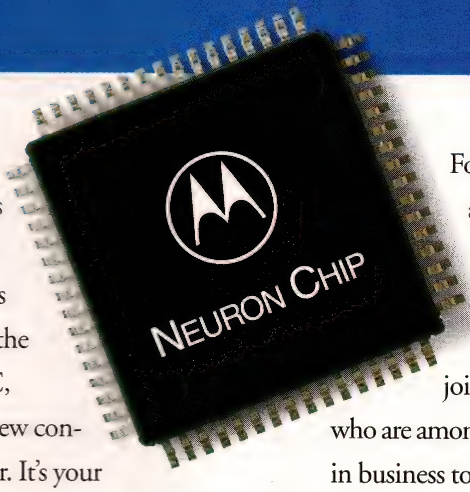

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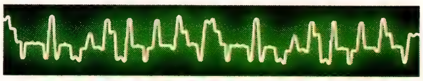

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TABLE 1—FUZZY-LOGIC TOOLS *(CONT)*

Source	Product	Description	Price
Inform GmbH Aachen, Germany (49) 2408 6090 **Circle No. 358** Evanston, IL (708) 866-1838 **Circle No. 359**	Fuzzytech Standard Edition	Windows-based tool generates 8- and 16-bit C code. Has graphics editor and simulator. Works with optional remote real-time debugger and optional neural-net module.	$999
	Fuzzytech Explorer Edition	Limited version of Standard Edition. Generates 16-bit C code.	$199
	Fuzzytech MCU Editions	Generates C code and assembly code for µCs. Versions available for Motorola 8051, Intel 80C196, Siemens 80166 and 81C99, Microchip Technology PIC, SGS-Thomson ST6, TI TMS320. Remote real-time debugger runs on PC and allows debugging of fuzzy applications running in embedded 80C196.	$1690 to $2090 $2840
Intel Corp Santa Clara, CA (800) 468-8118 **Circle No. 360**	Fuzzytech MCU-96 Edition	Inform's Fuzzytech MCU Edition for MCU-96 family.	$2056
	Fuzzybuilder (FUZZYBLDRMCU96)	Hardware/sofware kit that includes Fuzzytech MCU-96 Edition and Intel's ProjectBuilder 196. Options include NeuroFuzzy module and real-time remote cross debugger	$2096 to $4896
	Fuzzytech Explorer-96 Edition	Inform's Fuzzytech Explorer Edition for MCU-96 family.	$215
	Fuzzybuilder (FUZZYBLDREXP96)	Hardware/sofware kit that includes Fuzzytech Explorer-96 Edition and Intel's ProjectBuilder 196.	$396
	Fuzzytech MCU-51 Edition	Inform's Fuzzytech MCU Edition for 8051 family.	$1932
Integrated Systems Inc Santa Clara, CA (408) 980-1500 **Circle No. 361**	RT/Fuzzy Module	Tool for X Window systems is part of SystemBuild product for modeling and simulating complex control systems. Generates real-time fuzzy-logic code in C or Ada.	$5000
Microchip Technology Chandler, AZ (602) 963-7373 **Circle No. 362**	Fuzzytech	Tools from Inform for PIC µCs.	N/A
Modico Inc Knoxville, TN (615) 531-7008 **Circle No. 363**	Fuzzle	DOS-based tool with graphical interface generates C and Fortran code. Compiler required to generate executable code, but not to develop inference engines. Windows version due this fall.	$275
Motorola Inc Austin, TX Contact local office **Circle No. 364**	M68HXBFIDS	Version of Fide from Aptronix generates assembly code for 68HC05 and 68HC11.	$995
	FLEDKT01	Education kit includes demo version of Fide. Generates C and assembler code for 68HC05, 68HC11, 68HC16, and 68300. Includes neural-net capabilities.	$195
National Semiconductor Corp Santa Clara, CA (800) 272-9959 **Circle No. 365**	NewFuz4-C Development Kit	Windows-based development system uses neural networks for automatic creation of fuzzy rules and membership functions from input data sets. Generates C code and COP8 assembly code. Includes simulator.	$15,000
	NeuFuz4-C Learning Kit	Limited-capability version of NewFuz4-C.	$399
	NeuFuz4 Development Kit	Windows-based development system uses neural networks for automatic creation of fuzzy rules and membership functions from input data sets. Generates COP8 assembly code; includes some COP8 software tools.	$3975
	NeuFuz4 Learning Kit	Limited-capability version.	$199

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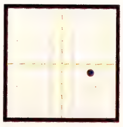

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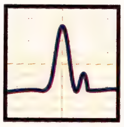

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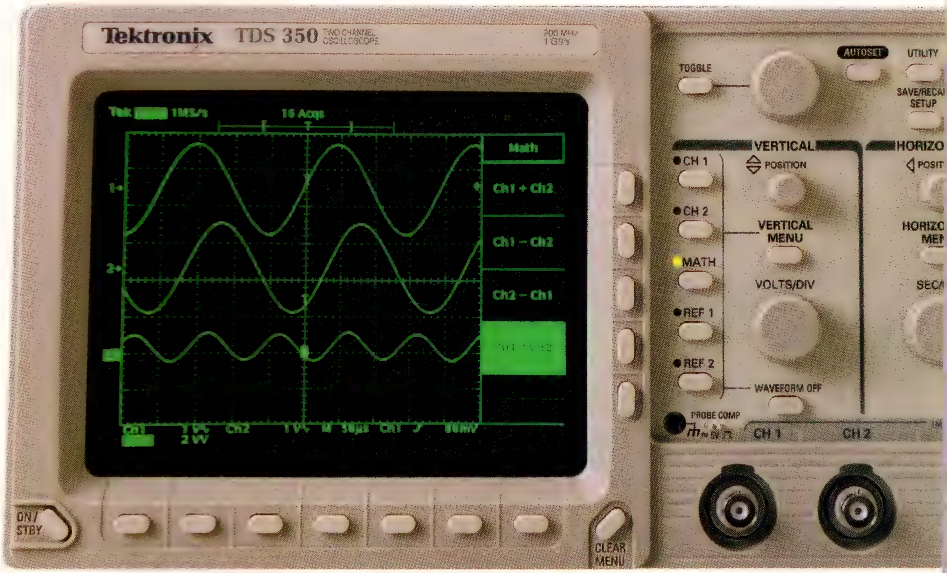

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Source	Product	Description	Price
NeuraLogix Inc San Jose, CA (408) 383-7200 **Circle No. 366**	Insight	Windows-based development system for NeuraLogix NLX22X family of stand-alone fuzzy-logic controllers Includes simulator. Has features unique to NLX22X hardware.	$995
NeuralWare Inc Pittsburgh, PA (412) 787-8222 **Circle No. 367**	FuzzySP	Windows-based fuzzy-logic tool for business applications such as market analysis and risk assessment.	$2995
	FuzzyEmbed	Software module that enables embedding fuzzy logic developed with FuzzySP into application software.	$495
SGS-Thomson Microelectronics Milan, Italy: (39) (2) 575 461 **Circle No. 368** Phoenix, AZ: (602) 867-6259 **Circle No. 369**	Fuzzytech	Tools from Inform for ST6 µCs	N/A
Siemens Semiconductor Group Munich, Germany (49) 89 4144 8223 **Circle No. 370** **Siemens Corp** Santa Clara, CA: (408) 777-4500 **Circle No. 371**	Fuzzytech	Tools from Inform for 80C166 family, 8051, 81C99 fuzzy coprocessor.	N/A
Texas Instruments Inc Dallas, TX (800) 477-8924, ext 4500 **Circle No. 372**	Fuzzytech MCU-320 Edition	Windows-based tool developed with Inform generates C and assembly code for TMS320 DSP family.	$1890
	Fuzzytech MCU-320 Explorer Edition	Reduced-capability version of MCU-320 Edition. Generates DSP assembly code.	$199
Togai Infralogic Inc Irvine, CA (714) 588-3800 **Circle No. 373**	TILShell Professional Edition	Windows-based graphical tool generates C code. Extensive features include simulator, matrix rule editor, on-line debugger, and TILGen neural-net module.	$3495
	TILShell Standard Edition	Same as Professional Edition, but without on-line debugger and TILGen.	$1795
	TILShell+	Like TILShell Standard Edition, but without matrix rule editor and some other capabilities.	$795
	MicroFPL development system	Optional software modules generate assembly code for specific µCs and assemblers (included). Versions available for 8051; 6811; Hitachi H8/300, H8/500, and HMCS400; and Oki 65000 and 66000.	$595
	FuzzyCLIPS	Windows-based tool adds fuzzy-logic capability to C Language Integrated Production System (CLIPS), which NASA developed.	$199 to $899
VLSI Technology Inc San Jose, CA (408) 434-3000 **Circle No. 374**	TILShell	TILShell family of tools from Togai supports VY86C500 fuzzy-logic FSB coprocessor accelerator core and VY86C570 fuzzy-logic coprocessor.	N/A

Super Circle Number

For more information on fuzzy logic products available from all of the vendors listed in this box, you need only circle one number on the postage-paid reader service card.

Circle No. 375

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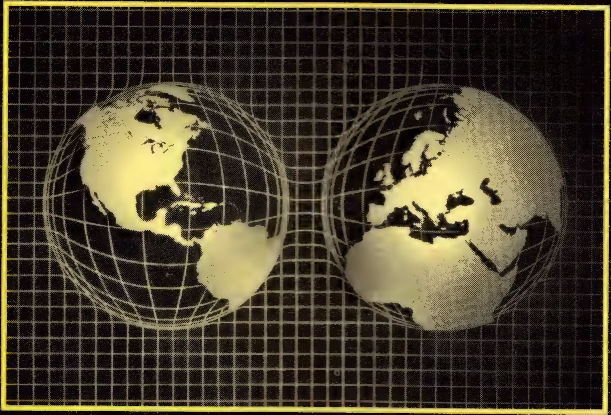

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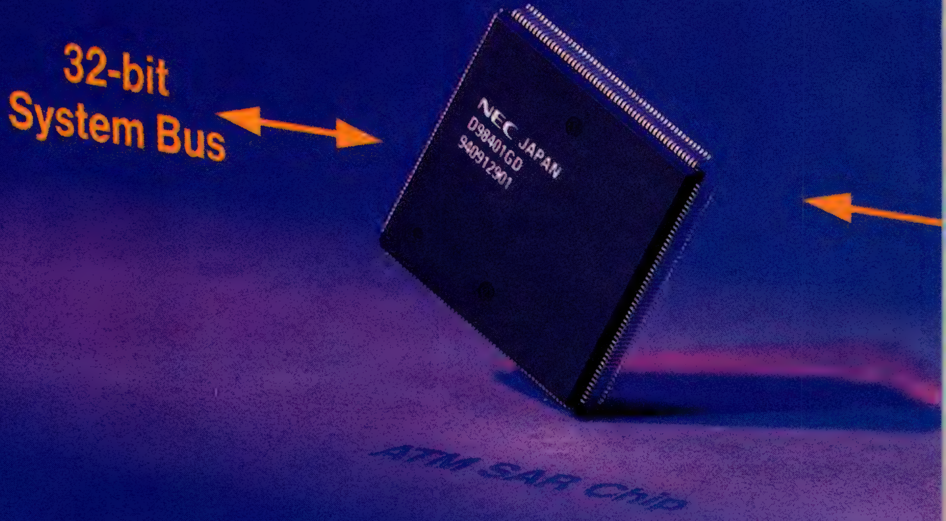

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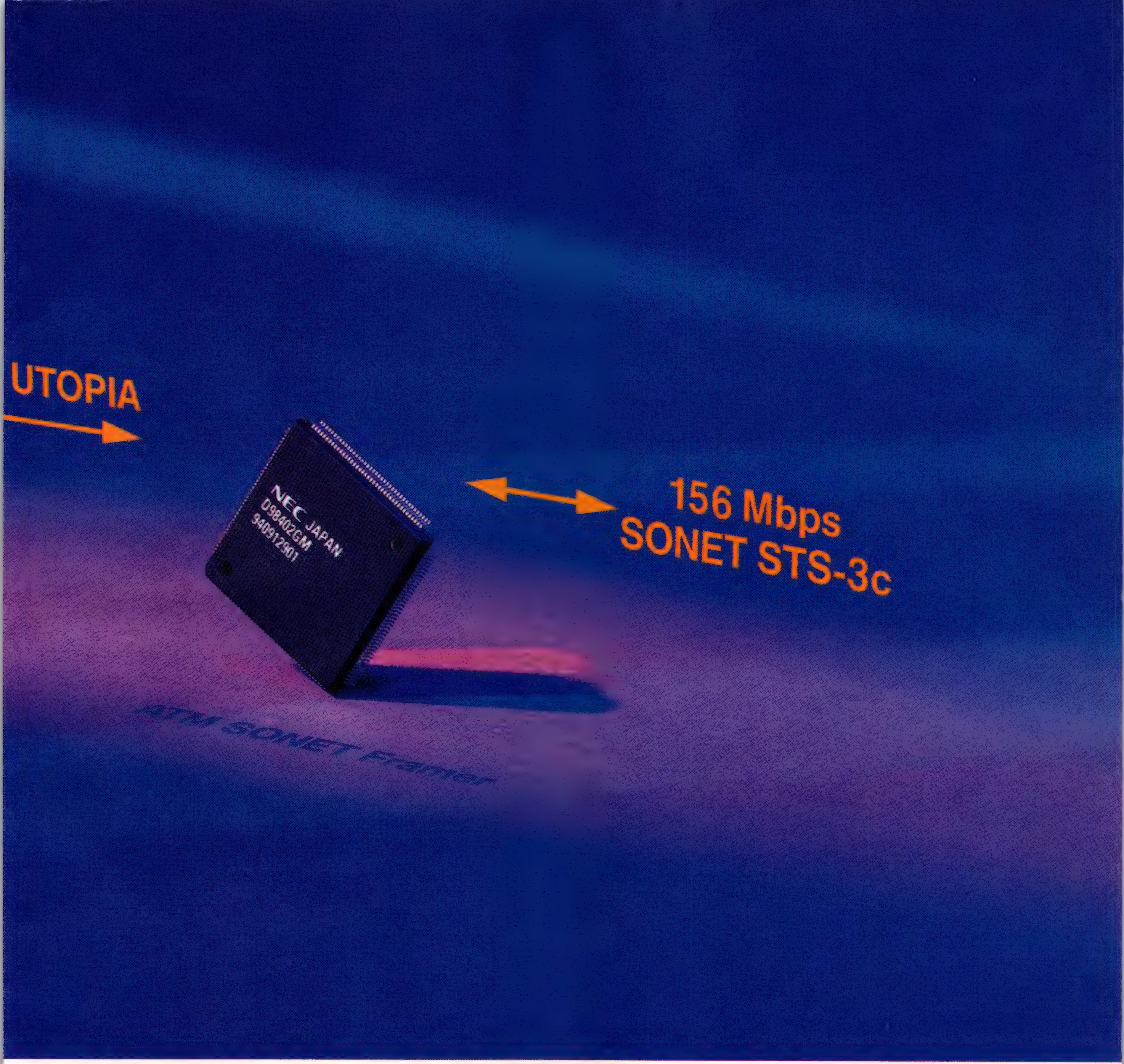

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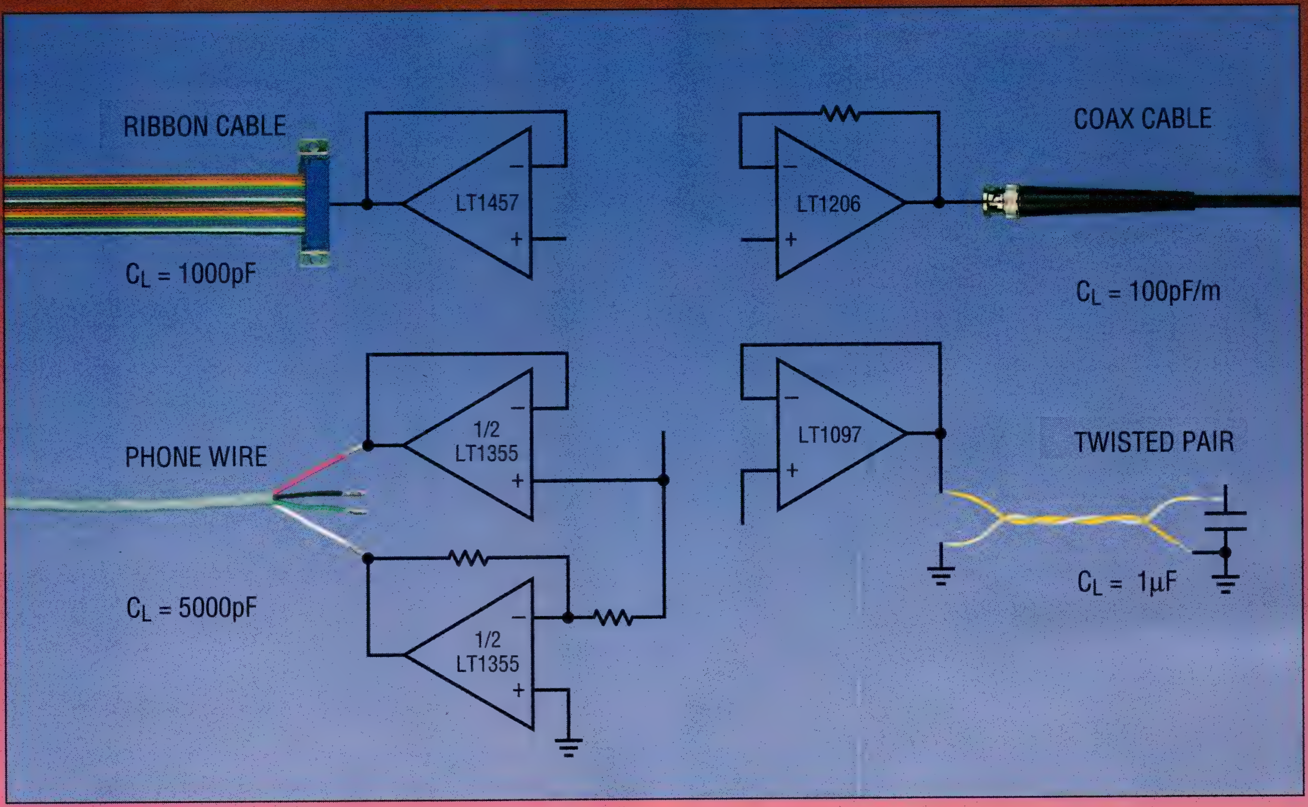

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Part #	Max V_{OS}	Max I_B	Min I_{OUT}	Bandwidth	Slew Rate
LT1097*	60µV	350pA	5.7mA	700kHz	0.2V/µs
LTC1152	10µV	100pA	4mA	1MHz	1V/µs
LT1206	10mV	5µA	250mA	60MHz	900V/µs
LT1220	1.0mV	300nA	24mA	45MHz	250V/µs
LT1224*	2.0mV	8µA	24mA	45MHz	400V/µs
LT1354*	800µV	300nA	30mA	12MHz	400V/µs
LT1357*	600µV	500nA	30mA	25MHz	600V/µs
LT1360*	1.0mV	1µA	40mA	50MHz	800V/µs
LT1363*	1.5mV	2µA	70mA	75MHz	1000V/µs
LT1457	800µV	75pA	10mA	1.7MHz	4V/µs

*Duals and Quads are available.

Specifications for the table shown are low cost grades in plastic DIP. Prices for our C-Load op amps start as low as $1.05 for the LT1097CN8. For details, contact Linear Technology Corporation, 1630 McCarthy Blvd., Milpitas, CA 95035/408-432-1900. For literature only, call **1-800-4-LINEAR**.

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CIRCLE NO. 80

Negatrons enrich filter, oscillator designs

Aleksandr Belousov, Baltimore, MD

The latest wave of high-performance op amps allows you to incorporate "negatrons" (synthesized negative resistors) into your oscillators and filters. **Fig 1** shows the universal filter/oscillator circuit based on a simulated lossy inductor and a negative resistance, which compensates the lossy inductor. Note that the circuit has no physical inductors. The performance of this circuit is very predictable and repeatable.

Op-amp IC_2 and its associated components form a gyrator that simulates the inductance $L_{EQ}=C_2R_4R_5$. Paralleling L_{EQ} with C_1 forms a parallel-resonant LC tank circuit. Op amp IC_1 and its associated components form the negatron that simulates a negative resistance, $-(R_1R_3)/R_2$.

Fig 2 shows the simplified equivalent circuit of **Fig 1**'s circuit. Obviously, to obtain continuous oscillation from IC_2's simulated tank circuit, you must trim its shunt resistance to zero or a negative value. Otherwise, oscillations would simply die out. IC_1's negatron cancels the tank circuit's shunt resistance.

One further detail: To stabilize the amplitude of oscillation, you must implement a nonlinear circuit in IC_1's negatron. The simplest solution is the diode clamp, comprising D_1, D_2, and R_C, in parallel with **Fig 1**'s R_2.

Configured as an oscillator, the circuit produces a 1V-rms, 1-kHz sinewave having <1% THD at OUT_1. OUT_2 produces a 0.7V-rms sinewave, 90° phase-shifted from OUT_1's signal. The inexpensive LM358s in **Fig 1** work fine up to 100 kHz. For higher frequencies, you have to use faster and more expensive op amps.

To configure the circuit as a filter, first remove the clamping diodes and R_C and then disconnect the input IN from ground. Next, trim R_2 to more than 7.5 kΩ. You can use OUT_1, OUT_2, or both, simultaneously. OUT_1 is a bandpass output, and OUT_2 is a lowpass output; OUT_2 is still 90° phase-shifted from OUT_1.

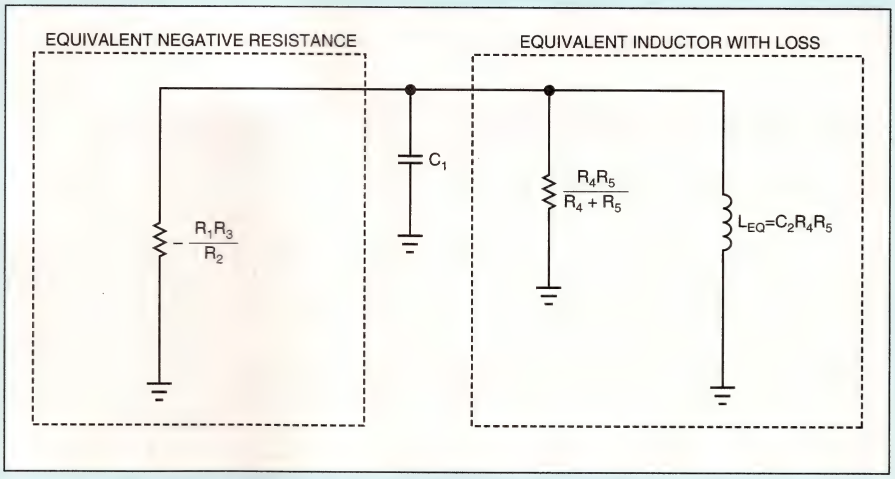

Fig 2—These two basic building blocks allow you to design oscillators and filters that incorporate no physical inductors.

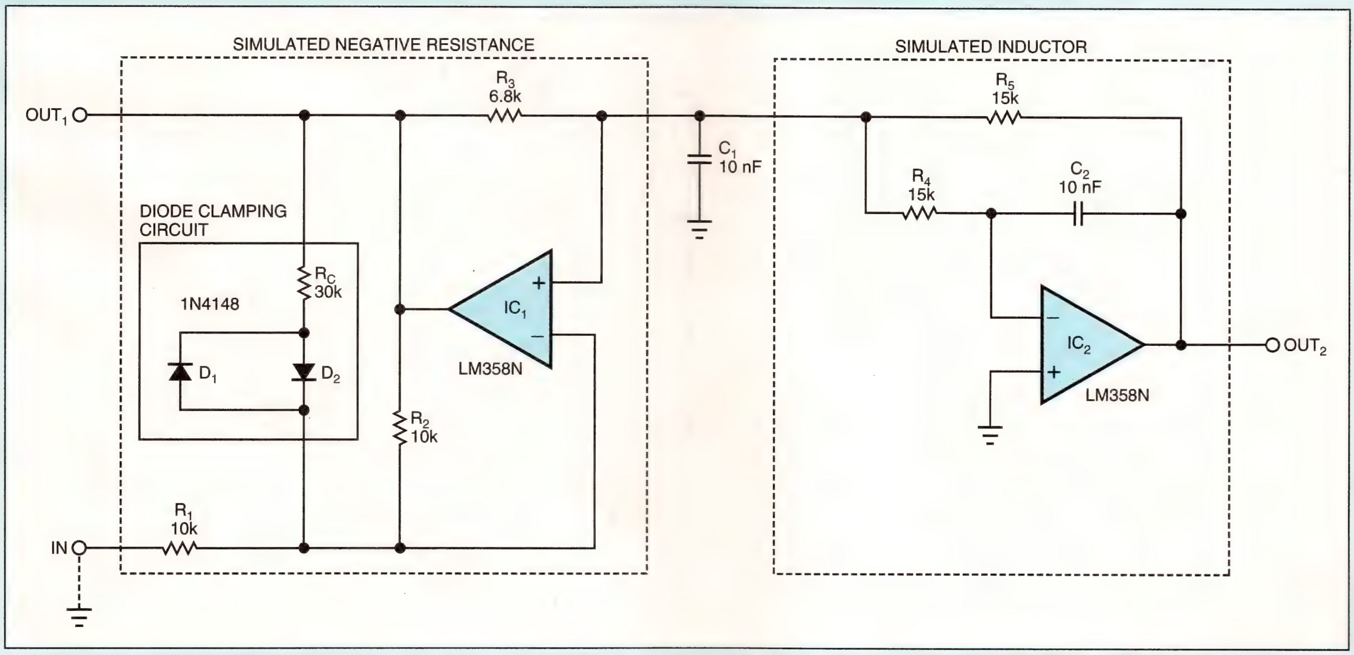

Fig 1—These simple circuits implement a negatron and a gyrator. The gyrator and C_1 form a resonant tank circuit. The negatron cancels the gyrator's shunt resistance.

With R_2 set to 10 kΩ, **Fig 3** shows the circuit's response to a 0.5V-rms input. The filter's maximum resonant amplification is approximately 18 dB at the 1-kHz center frequency, f_C. You can adjust f_C by varying R_4, R_5, C_1, or C_2. Varying R_2 adjusts the filter's Q factor separately from its f_C. (DI #1560)

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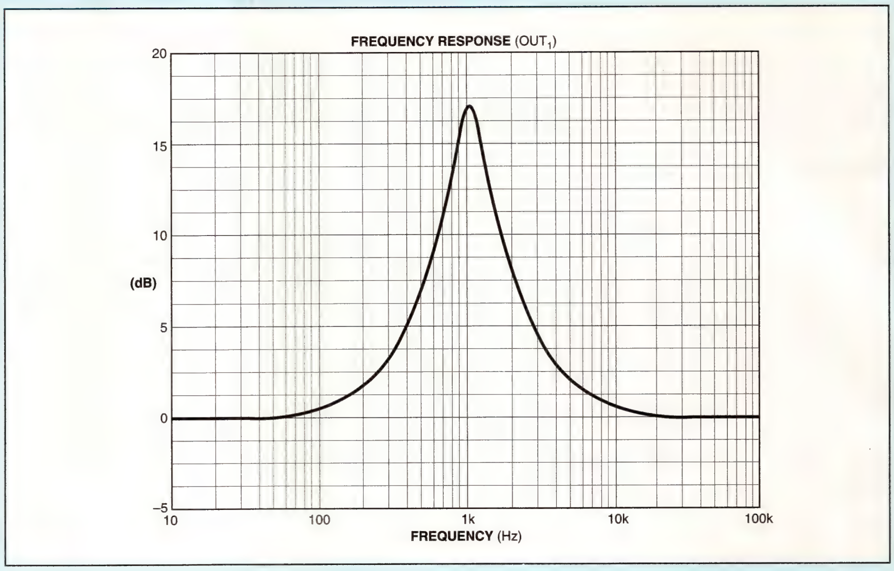

Fig 3—Configured as a filter, Fig 1's OUT_1 output is a bandpass-filter output.

Op-amp rectifier signals input state

Lee E Scaggs, High Country TEK, Nevada City, CA

The op-amp rectifier in **Fig 1** operates from a single supply and provides a logic output and an LED that indicate the state of the input voltage. The input-state indications are handy for calibration.

Because the circuit operates from a single supply, the 2.5V reference determines the level around which the circuit rectifies input waveforms.

In operation, if the input is above the 2.5V reference level, IC_{2D} acts as a follower. Therefore, the inputs to R_1 and IC_{2B}'s noninverting input track the input. IC_{2B}'s output also tracks the input signal. The output of IC_{2A}, acting as a comparator, goes to 0V.

If the input goes below the 2.5V reference level, IC_{2A}'s output goes positive, clamping its inverting input to the 2.5V reference (plus or minus the input offset). IC_{2B} now becomes a gain-of-1 inverter. IC_{2A} lights the LED and, with the help of D_1 and D_2, provides a high logic-level output. If you need a higher output logic level, add another diode to the D_1/D_2 string or change D_2 to a low-value Zener diode. (DI #1561)

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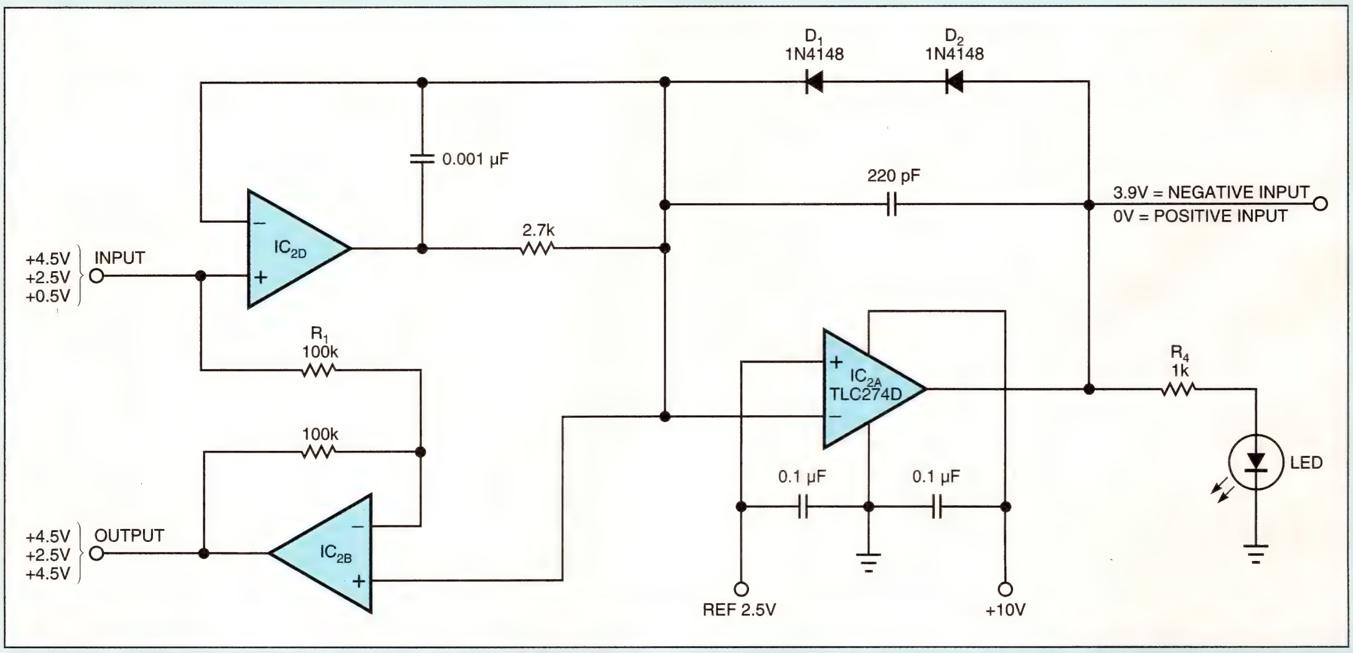

Fig 1—This op-amp rectifier has no diodes in its rectifying circuit (D_1 and D_2 help provide a logic-level output) and provides an LED and logic output as an aid to calibration.

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All-digital circuit fires triacs

Robert Trescott Jr, GTE ImagiTrek, Carlsbad, CA

The simple digital circuit in **Fig 1** allows a µP to control ac power precisely without using any digital-to-analog circuitry.

In operation, binary-comparator IC_2 compares a data word held in latch IC_1 to the output of a ripple counter, IC_3. The system's controlling computer loads the desired data word into IC_1.

A 1-MHz clock drives IC_3, providing very fine timing resolution for 50- or 60-Hz power. At the ac power's zero crossing, optoisolator IC_4 clears ripple counter IC_3, synchronizing the ripple counter with the ac line. At the zero crossing, the binary comparator's output also goes inactive. The binary comparator's output controls an isolated triac driver, IC_5.

After the next zero crossing, the counter proceeds to count up. The binary comparator holds its output inactive until the count exceeds the latched data. The triac then switches on for the duration of the ac half-cycle until the next zero crossing occurs.

You can add more ac power-control channels by replicating the latch, comparator, and triac driver. The clock's ripple counter can drive several channels at once. Inserting an EPROM or a PAL device between the ripple counter and the binary comparator allows you to generate exponential, logarithmic, or arbitrary waveforms. (DI #1562) EDN

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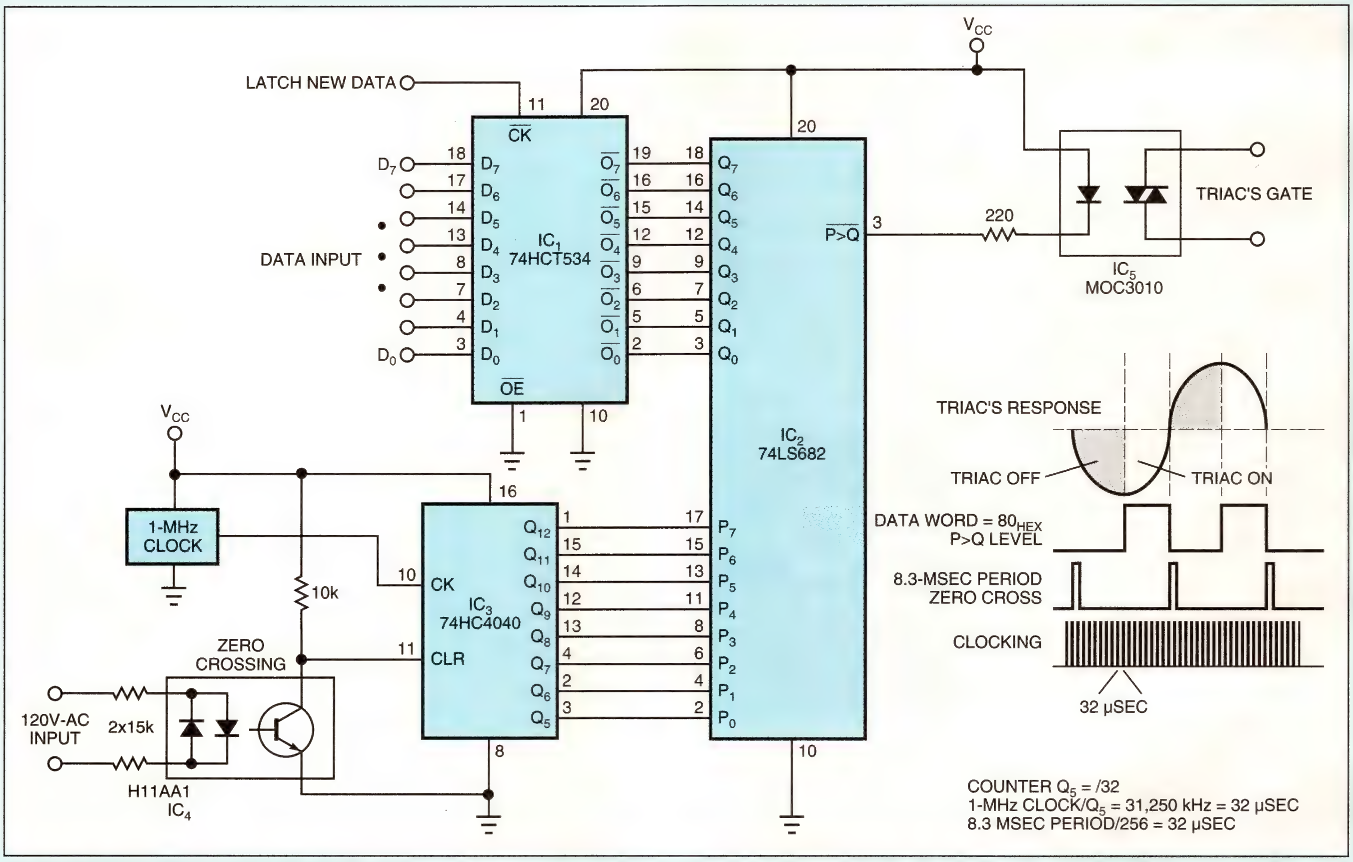

Fig 1—By comparing a preset digital word to the output of a ripple counter synchronized to the ac power, this circuit allows a µP to precisely control an ac load without resorting to digital-to-analog circuitry.

Simple timer exploits op-amp bias current

Aleksandr Belousov, Baltimore, MD

The simple, low-cost analog timer in **Fig 1** exploits the parasitic input-bias current of op-amp IC_1. The timer achieves long time delays even though it uses only low-value, inexpensive ceramic chip capacitors. After all, because the input-bias current *is* the minimum current flow into an op amp, this method produces the longest time delays possible from a given capacitor and op amp.

In operation, the op amp's inverting input draws an input-

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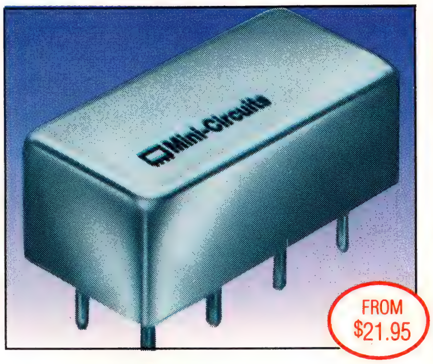
The new ZP-11A mixer from Mini-Circuits offers space-saving miniature construction plus ultra-high reliability backed by a five-year guarantee.

Frequency range is 1400-1900MHz RF/LO, 40-500MHz IF, and conversion loss specifications are statistically controlled to better than 4.5σ from mean.

Conversion loss is flat (0.6dB typical) over the full range and 1dB compression is 1dB typical.

The unit is housed in a miniature connectorized package.

CIRCLE NO. 93



NEW MIXER OFFERS WIDE FREQUENCY COVERAGE

The SBL-173SH mixer from Mini-Circuits provides a wide frequency coverage of 5-1200MHz, as well as 1dB compression of 14dBm typical. The device also boasts excellent isolation performance: L-R and L-I are both 35dB typical. Absolute maximum power ratings are: RF power 200mW; IF current, 40mA. Operating temperature range is -55°C to +100°C.

CIRCLE NO. 102

HIGH POWER 8-WAY COMBINER/SPLITTER

Ideal as a power combiner in VHF transmitter applications, the ZB8CS-950-32W from Mini-Circuits features low insertion loss (0.4dB typical) and high 30dB isolation plus 32W performance. This is combined with amplitude unbalance of only 0.1dB and phase unbalance of only 1.0°.

Over the -55°C to +55°C operating temperature range for full power, derating is linear to 20% at 90°C.BNC connectors are standard with SMA and type N options.

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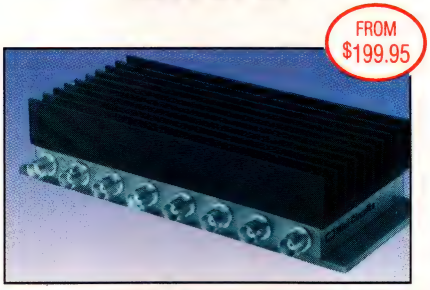

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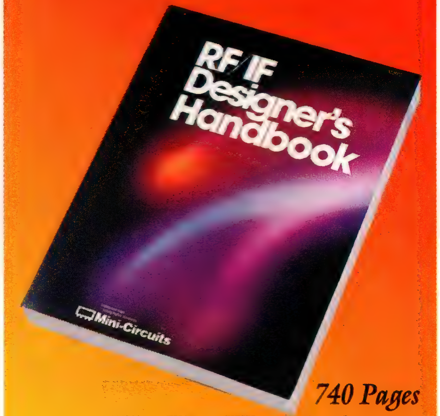

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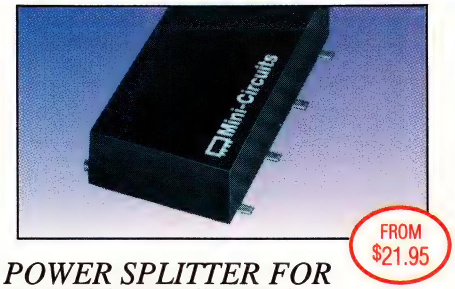

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With a wide 800-1000MHz bandwidth, the SCP-4-4 is a new high-performance surface mount 4-way power splitter designed for telecommunications, radio and remote control applications.

Features include high isolation (24dB typical) and low insertion loss (0.9dB typical). Input VSWR is typically only 1.3:1 and 1.15:1 at output. Maximum ratings are: 0.5W power input, 0.125W internal power dissipation.

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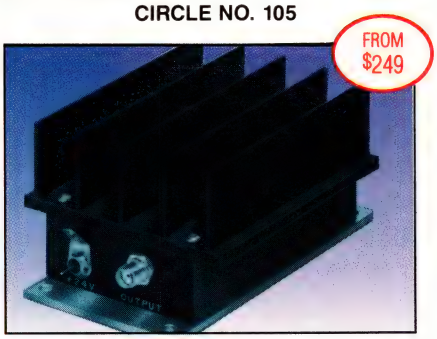

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CIRCLE NO. 106

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bias current, I_B, from resistive divider $R_1/R_2/R_3$. The voltage at the R_2-R_3 junction is V_{REF}. A current approximately equal to I_B also charges capacitor C_1, producing a linear voltage ramp.

Assuming that C_1 is initially discharged (by pushing SW_1), the delay time that IC_1, functioning as a comparator, takes to change state equals $V_{REF} \times C_1/I_B$. And, as a first approximation, this time constant is independent of I_B. While IC_1's output is low, it briefly lights the lamp L_1 via Q_1, SCR_1, and associated components.

This circuit configuration takes care of newer op amps whose input-bias current is less than 1 nA. Otherwise, for older, high-input-bias-current op amps, just wire the inverting input of the op amp to ground directly through a resistor. The resulting circuit's time constant would be that resistor's value multiplied by C_1's. However, for today's low-input-bias-current op amps, the value of this grounding resistor would have to be exceedingly high to produce usable time constants. (DI #1565) EDN

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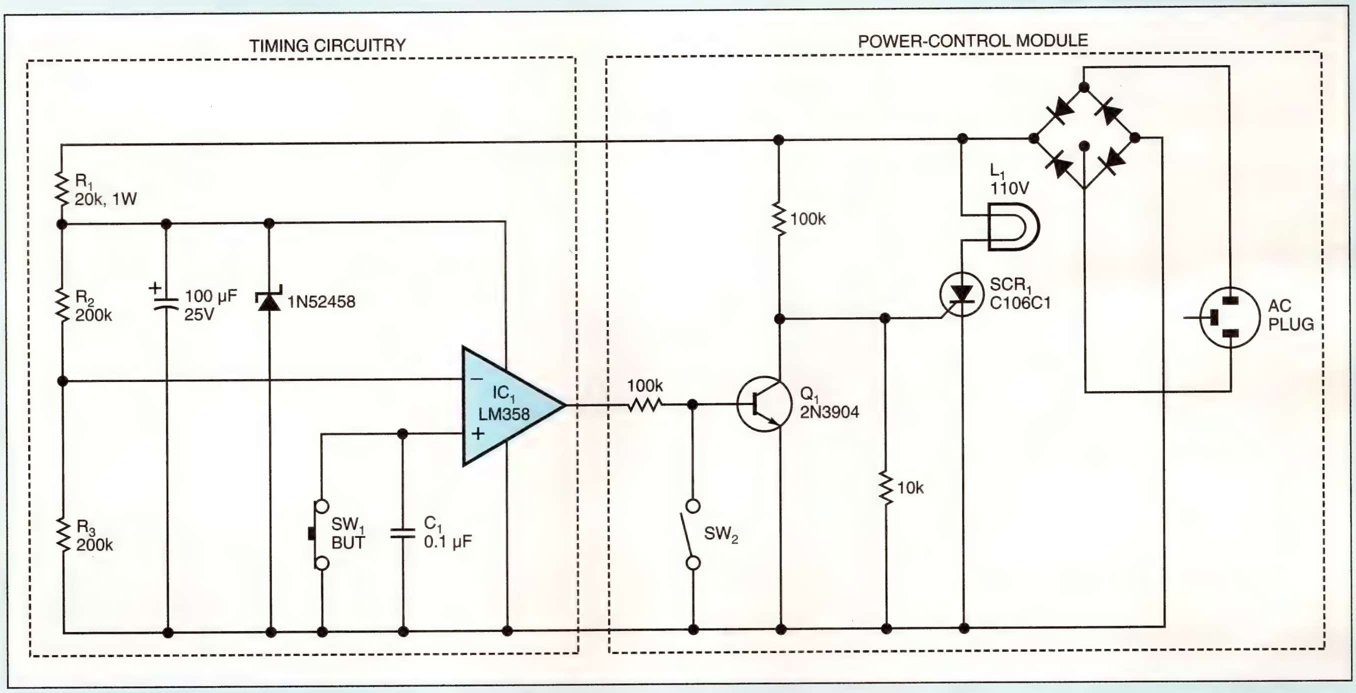

Fig 1—Exploiting the tiny input-bias current of op-amp IC_1 to charge C_1, this simple timer circuit produces the longest possible delays for a given op-amp/capacitor combination.

Speedy Spice subcircuit models lossy line

Patrice Tesson, Laboratoire IXL, Bordeaux, France

Fig 1 (or its equivalent, **Listing 1**) is a simple and efficient Spice model for a transmission line with constant resistive losses. The model is an extension of the Spice transmission-line model (designated Txxx).

Some commercial versions of Spice offer models for lossy transmission lines. However, these models are lumped-element models. These models require many cells to give accurate results for relatively long delays. Having many cells causes long calculation times.

The model in **Fig 1** executes quickly, is compatible with any Spice-type commercial program, and is a very interesting alternative to the lumped-element models.

A trace's length, ln, and parameters Ll, Cl and Rl—inductance, capacitance, and resistance per unit length, respec-

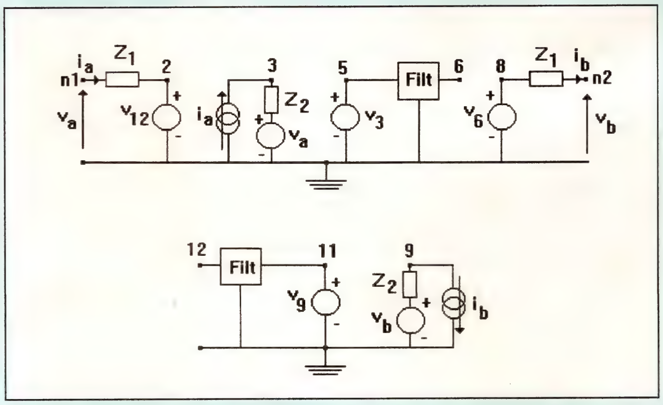

Fig 1—This Spice subcircuit models a lossy transmission line.

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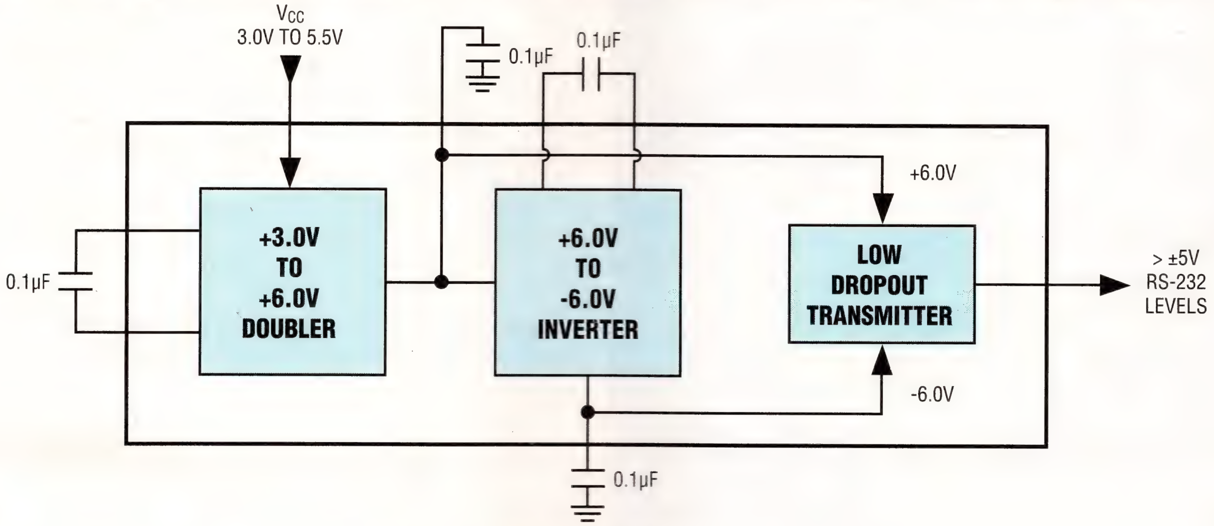

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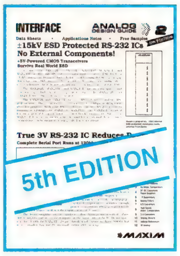
FEATURE	MAXIM MAX3241	VOLTAGE TRIPLERS	RESPECIFIED +5V
ARCHITECTURE	Doubler	Tripler	Doubler
NUMBER OF Tx/Rx	3/5	3/5	3/5
SUPPLY CURRENT	1mA	**20mA**	8mA
DATA RATE	120kbps	20kbps	20kbps
V_{CC} RANGE	3.0V – 5.5V	3.0V – 3.6V	3.0V – 5.5V
EXTERNAL CAPS	4 x 0.1µF	5 x 1.0µF	4 x 1.0µF
OUTPUT VOLTAGE	> ±5.0V	> ±5.0V	> ±3.7V
MOUSE DRIVE	Yes	No	No



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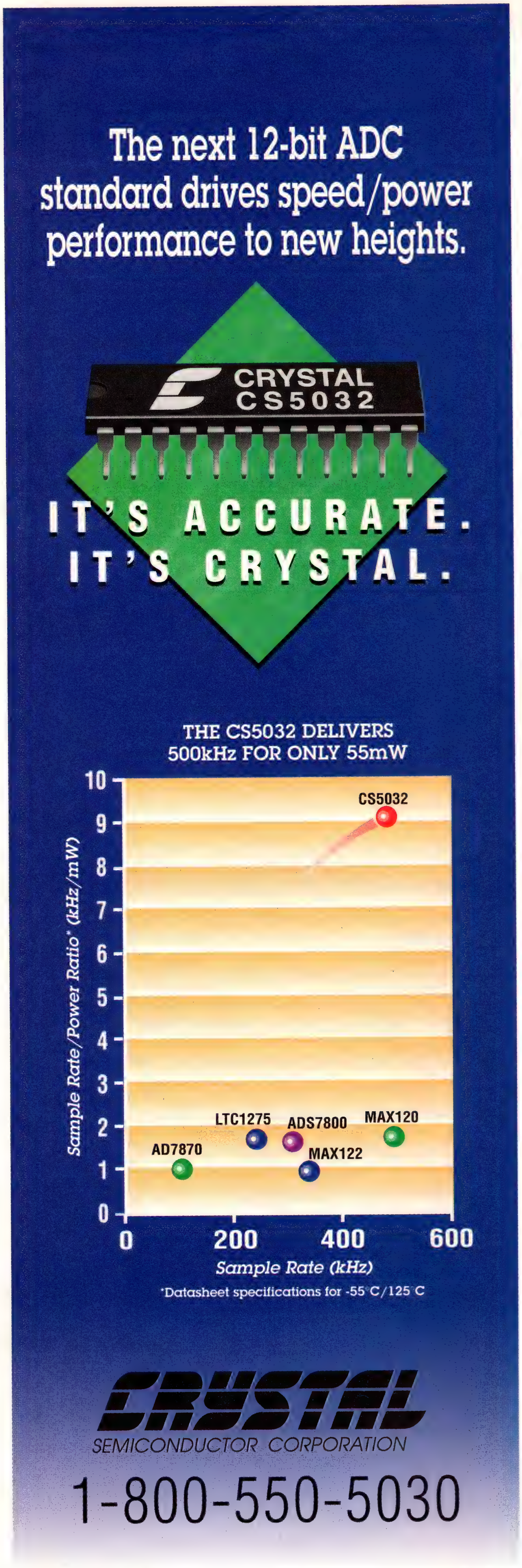

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tively—define the model. You must enter the line's parameters in the subcircuit's CALL statements this way:

Xyyy in ref out RLINE Ll = val Cl = val Rl = val ln = val

The model's basis is the first order of the frequency-dependent characteristic-impedance and exponential-propagation function of a lossy transmission line. This model is valid for high frequencies and corrects for the line's dc response. The model is very accurate for an interconnection that acts as a low-loss transmission line only if

$$t_S<8\times \mathrm{ln}\times\sqrt{\mathrm{Ll}\times\mathrm{Cl}}$$

and

$$\mathrm{Rl}\times\mathrm{ln}<2\sqrt{\mathrm{Ll}/\mathrm{Cl}},$$

where t_S is the switching time of the fastest signal. Be careful if you use the model for other cases. (DI #1566)

To Vote For This Design, Circle No. 405

Listing 1—Transmission-line model with constant resistive losses

```
.SUBCKT RLINE n1 g n2
.PARAM Z2 = 'sqrt(Ll/Cl)'   rln = 'Rl * ln'   td = 'sqrt(Ll*Cl)*ln'
+ a = 'rln/(2*Z2)'   b = 'exp(-1*a)'   c = 'td*(1+a)'
+ cp = 'c/rln'   cf1= '2*b*c'   cf2 = '2*c*(2-b)
X1 n1 1 Z1
Va 1 2 0
Evwa 2 g 12 g 1
Fia g 3 Va 1
Eva1 4 g n1 g 1
Ra 3 4 Z2
Eva2 5 g 3 g 1
X2 5 g 6 Filt
Evwb 7 g 6 g 1
Vb 7 8 0
X3 8 n2 Z1
Fib 9 g Vb 1
Evb1 10 g n2 g 1
Rb 9 10 Z2
Evb2 11 g 9 g 1
X4 11 g 12 Filt
.SUBCKT Filt 1 g 4
T 1, g 2, g Zo = 50 Td = td
Rc 2 g 50
E1 3 g 2 g 2
Rf1 3 4 0.5
Cf1 3 4 cf1
Rf2 4 g 0.5
Cf2 4 g cf2
.ENDS
.SUBCKT 1 3 Z1
 R1 1 2 Z2
 R2 2 3 rln
 C1 2 3 cp
.ENDS
.ENDS
```

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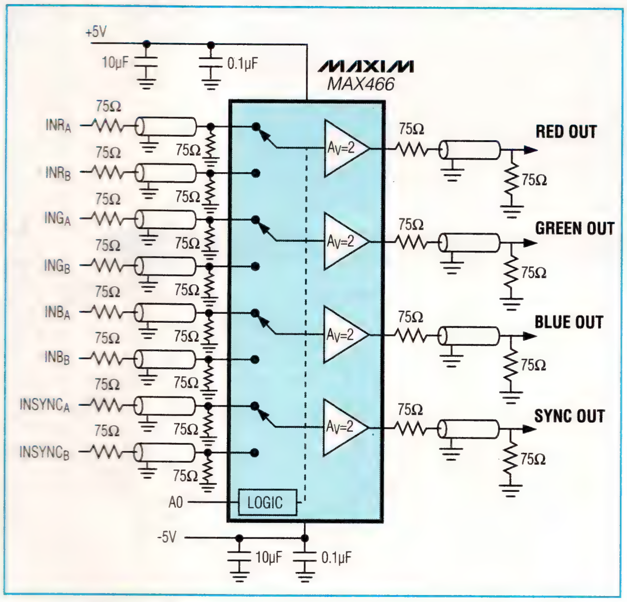
  MAX465/MAX466 (A_V = 2V/V)
- **300V/µs Slew Rate**
- **Hi-Z Output State**
- **5pF Input Capacitance**
- **±2.5V Output Swing Into 150Ω**



The MAX463-MAX466 are four new ±5V video ICs that switch between two RGB or RGB + Sync channels **and** include 100MHz output drivers. For design flexibility, the triple (RGB) or quad (RGB + Sync) versions are available with either unity-gain or fixed gain-of-two drivers for driving back-terminated coaxial cable. In addition, a high-impedance disable mode reduces supply current and allows multiple switches to be paralleled in larger networks.

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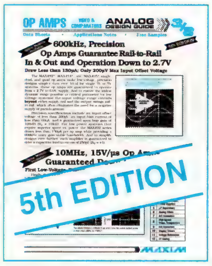
DEVICE	DESCRIPTION	VOLTAGE GAIN (V/V)	BANDWIDTH (MHz)	SLEW RATE (V/µs)	MINIMUM OUTPUT SWING (R_L = 75Ω)	Hi-Z OUTPUT STATE
MAX463	2-Channel RGB Switch with Output Drivers	1	100	200	±2.0V	YES
MAX464	2-Channel RGB + Sync Switch with Output Drivers	1	100	200	±2.0V	YES
MAX465	2-Channel RGB Switch with Output Drivers	2	90	300	±2.0V	YES
MAX466	2-Channel RGB + Sync Switch with Output Drivers	2	90	300	±2.0V	YES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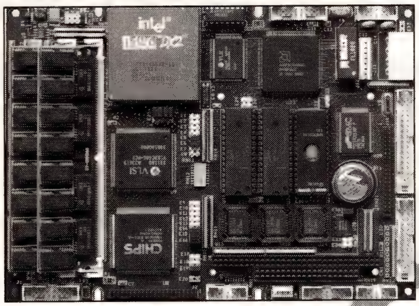

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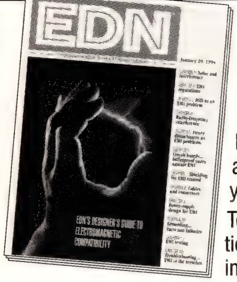

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SOFTWARE SHORTS

6805 μCs perform 32-bit math

Bill Lucas, Motorola
Richmond, VA

The math package in the ZIPfile attached to **EDN BBS /DI_SIG #1570** allows 6805 μCs to perform unsigned, 32-bit math. The subroutines contain the source code for add, subtract, multiply, and divide routines.

To Vote For This Design, Circle No. 406

Command-line collector meticulously classifies flags

Vladimir Bochev, Institute of Informatics
Sofia, Bulgaria

The C command-line collector in **EDN BBS /DI_SIG #1410** classifies everything on the command line after the program's name. With this routine, users no longer have to bother with abstruse parser-friendly restrictions, such as just where to put flags in the command line.

To Vote For This Design, Circle No. 407

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FEEDBACK AND AMPLIFICATION

Corrections

In Design Idea #1426, "Ring oscillator measures cable length," (*EDN*, May 12, 1994, pg 90), a 100m cable yields a 1-MHz oscillation frequency, not 600 MHz as stated in the text. *EDN* regrets that the names of the Design Idea's coauthors, S Paasch and K Mentzer, were inadvertently omitted.

In addition, the circuit diagram for Design Idea #1417, "Comparator improves regulator's efficiency" by Christophe Basso (*EDN*, April 28, 1994, pg 72), contains an extra connection dot. Delete the connection dot that joins the trace from C$_2$ to R$_1$ with the trace that runs from IC$_1$'s RT/CT pin to the 22-nF capacitor.

In "Monitor follows PC's power-on self-test," by Jerzy Chrzaszcz, (*EDN* September 16, 1993, pg 124,) the signal labeled LOW should be IOW.

In "Comparator improves regulator's efficiency," by Cristophe Basso, *EDN* April 28, 1994, an erroneous connection dot joins the trace running between IC$_1$'s RT/CT pin and the 22-nF capacitor with the trace running from R$_2$ to C$_2$.

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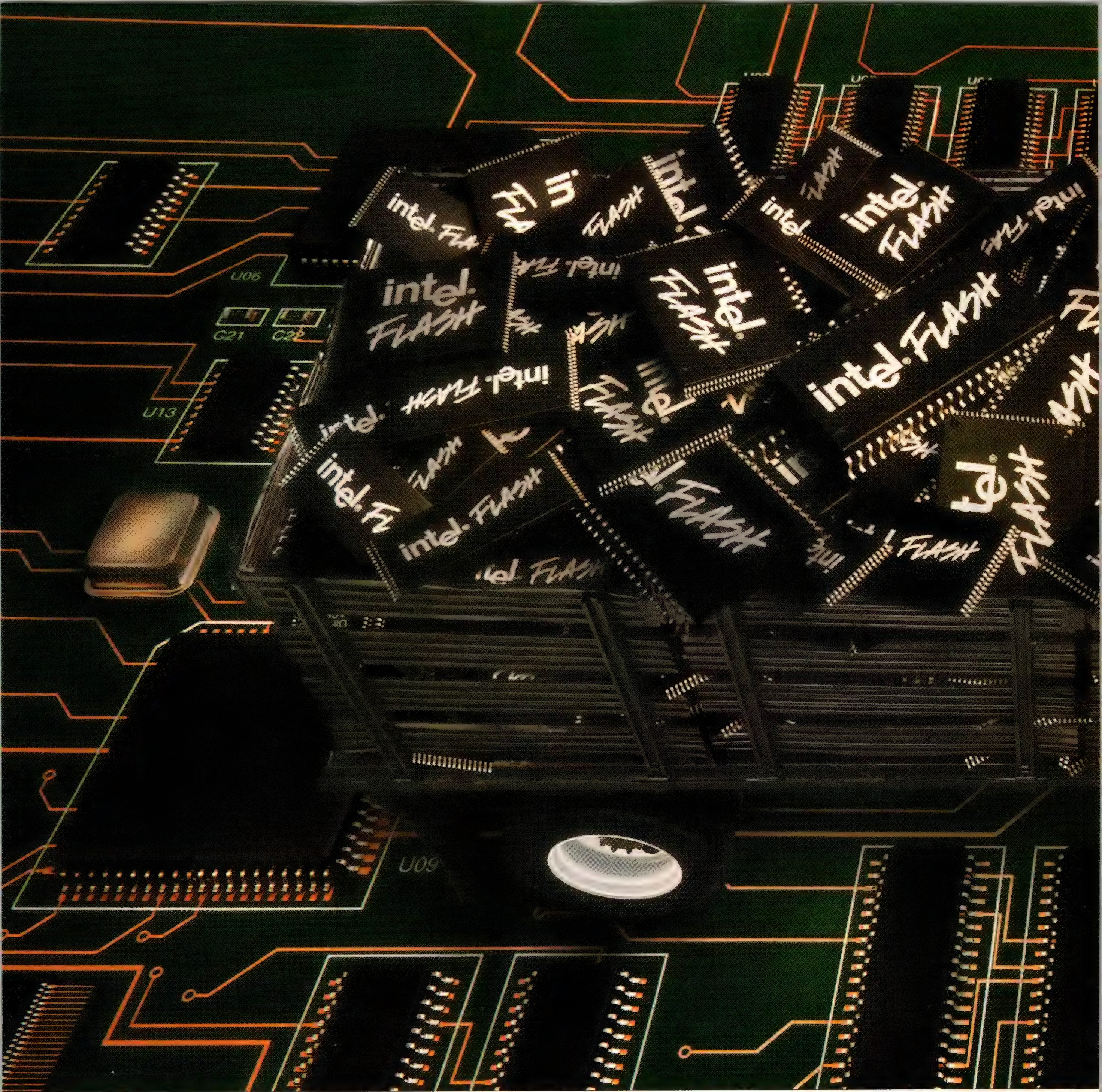

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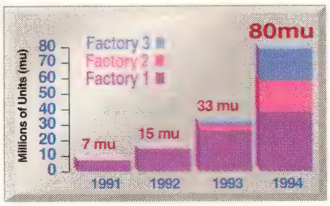
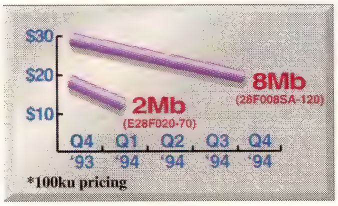

Intel Flash Memory Factory Output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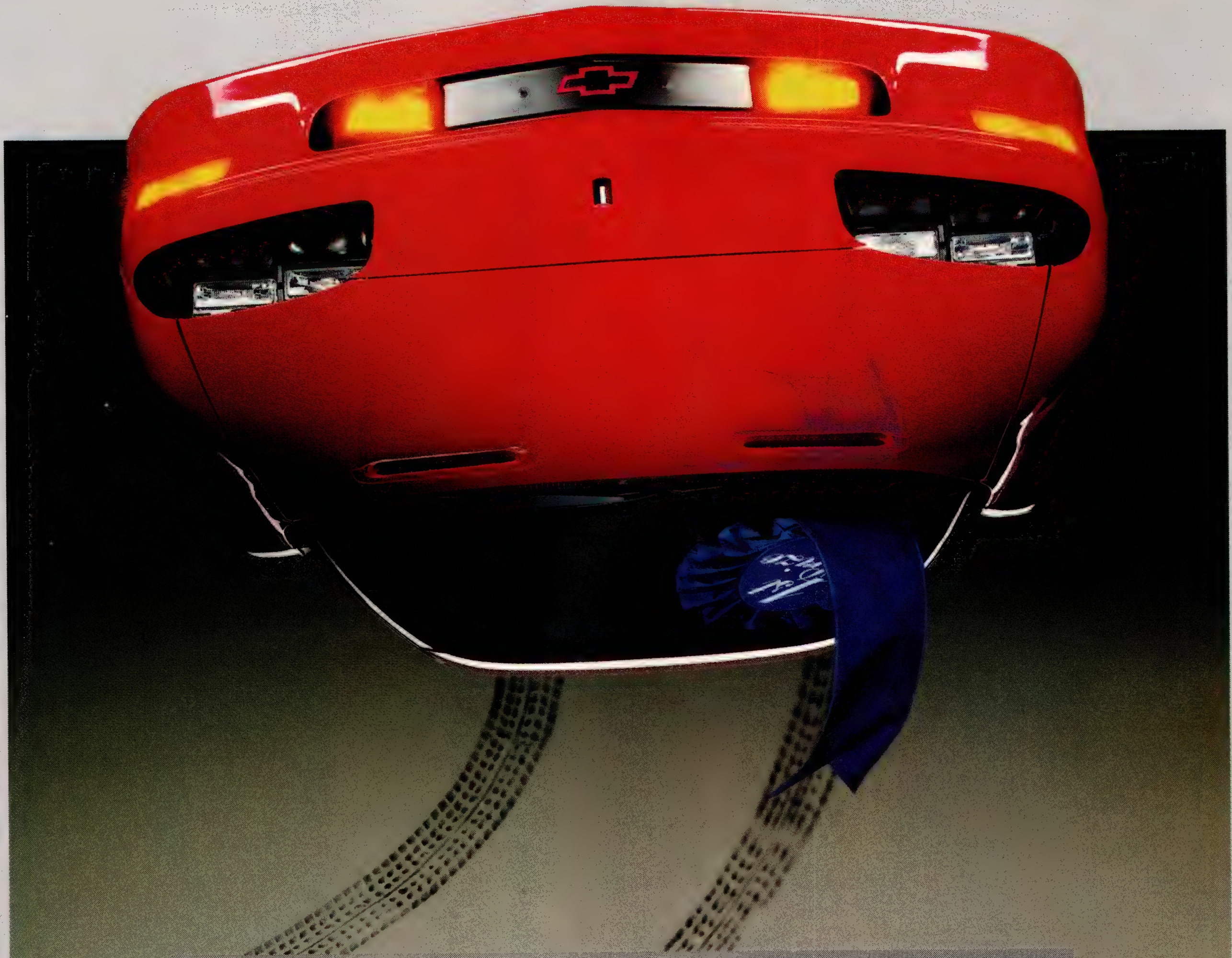

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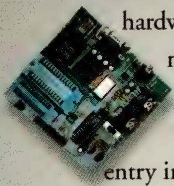

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Asynchronous conversion thwarts incompatibility in sampling A/D systems

Robert Adams, Analog Devices Inc

By using asynchronous sample-rate conversion, you can eliminate the problem of repeated or dropped samples that can occur when interconnecting systems with incompatible clock rates.

A technique known as "asynchronous sample-rate conversion" (ASRC) solves two problems you commonly encounter in communications between digital systems. An ASRC system acts as a universal buffer between incompatible audio sample rates and solves the problem of communication between systems where both try to act as clock "masters."

Before going into the details of ASRC, it's useful to explore the rationale behind its development. Digital audio has provided the major impetus. A decade ago, most audio signals were recorded, stored, and delivered in analog form to the end user. Today, the trend is to use digital techniques wherever possible to avoid the loss of signal quality that inevitably occurs with analog technology. An obvious example is the modern CD player, where the superb signal quality of digital sound has found nearly universal acceptance as the new standard for music distribution.

In the early days of digital audio, interconnection between pieces of equipment was implemented mostly in the analog domain, and each part of the chain came with its own A/D and D/A converters. For example, the digital output of a CD player is first converted to analog form, then sent to a preamp for further processing. Inside the preamp, an A/D converter often converts the signal back to digital form to perform special effects, such as ambience enhancement (reverb), digital equalization, or Dolby surround-sound decoding. It did not take long to realize that a direct digital connection between components would eliminate the redundant A/D and D/A converters and consequently improve the signal quality.

As digital interconnection between components becomes more common, a new problem frequently arises: synchronization. For example, assume you wish to send a digital audio signal over a synchronous network. The network must act as the clock master: It requests data at a fixed rate from the data source (**Fig 1**). The data source is most likely producing data at a different sample rate from that of the network and wants to act as the clock master. If the two systems are connected with no attempt at synchronization, then samples may be repeated or dropped, depending on whether the network rate is higher or lower than the sample rate of the source. This example shows that it's not easy to interconnect two systems when both want to be the clock master.

Another example of synchronization's causing problems is a system in which you need to mix multiple sources with incompatible sample rates digitally. **Fig 2** shows a typical mixing console for which all the inputs are in digital form. You can synchronize many of the input sources to a common studio reference generator, but often one or more input chan-

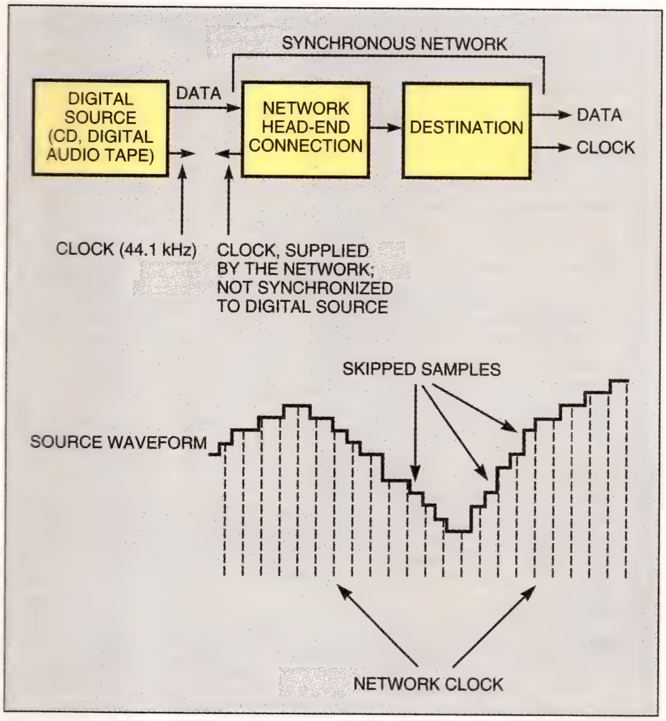
SYNCHRONOUS NETWORK
DIGITAL SOURCE (CD, DIGITAL AUDIO TAPE)
DATA
NETWORK HEAD-END CONNECTION
DESTINATION
DATA
CLOCK
CLOCK (44.1 kHz)
CLOCK, SUPPLIED BY THE NETWORK; NOT SYNCHRONIZED TO DIGITAL SOURCE
SKIPPED SAMPLES
SOURCE WAVEFORM
NETWORK CLOCK

Fig 1—Connecting a master-only digital source to a synchronous network can result in skipped or repeated samples, depending on whether the network clock is higher or lower than the sample rate of the source.

nels come from sources that cannot operate in a clock "slave" mode (for example, consumer CD or digital-audio tape signals, as well as audio from network connections). Again, this disparity in sample rates causes repeated or dropped samples to occur at regular intervals, resulting in audible errors.

In many cases, sample rates are nominally the same, but differ by the accuracy and tolerance of the internal clock generators. Again, because both the sender and the receiver are clock masters, repeated or dropped samples occur. **Table 1** summarizes some of the most popular audio sample rates and where they are used. If we want to include multimedia and networked audio applications, the list would become even longer.

Sync vs async sample-rate converters

Fig 3 shows the difference between synchronous and asynchronous sample-rate converters. In a synchronous converter (**Fig 3a**), the user sets the frequency ratio FS_{out}/FS_{in} explicitly, and the converter then produces output samples at the requested rate. The frequency ratio for such a device must be a rational number and is usually expressed as a ratio N/M. To keep the hardware compexity reasonable, N and M are usually quite small because using large values entails a large number of stored interpolation coefficients.

While a synchronous sample-rate converter is often useful, its output is still a clock master and thus does not solve any of the problems. What you need is an asynchronous sample-rate converter (**Fig 3b**), which provides correctly interpolated output data when requested from an external clock signal. The output sample-rate clock signal is now an input to the device, and the rate converter produces data upon request. The output is, therefore, a sample-clock slave, solving the problem of interconnection between multiple systems that all want to be the clock master.

For example, **Fig 4** shows a solution to the digital mixing-console problem in which each "wild," or unsynchronized, input uses an ASRC. The output clock of each ASRC ties to the internal system clock of the mixer. The input clock to each ASRC is derived from the serial input stream of each channel, using a PLL. The ASRC effectively decouples the internal and external sampling rates, and makes digital interconnection as easy as the analog interconnection of yesterday.

Synchronous rate-conversion theory

A synchronous sample-rate converter applies an explicit sample-frequency ratio FS_{out}/FS_{in} of N/M, and samples are then produced at a rate that is locked to the input rate. The ratio (both N and M integers) must be rational; furthermore, N and M should be quite small to avoid the requirement of large coefficient storage. From a signal-processing point of view, synchronous sample-rate converters are quite simple.

Fig 5 shows an example in which N/M=4/3. First, an interpolation by a factor of four takes place. This is done by inserting three zero-valued samples between input samples, which increases the sample rate by a factor of four. A digital filter for the higher sample rate of $FS_{in}\times4$ then removes the images. The digital filter's cutoff frequency is less than half the input or output sample rate, whichever is lower. The output of this filter is then decimated by three, a process that involves simply discarding two of every three samples at the output of the interpolation filter.

Fig 6 shows the direct-convolution model of an interpolation filter for N=4. The zero-stuffing causes only a subset of

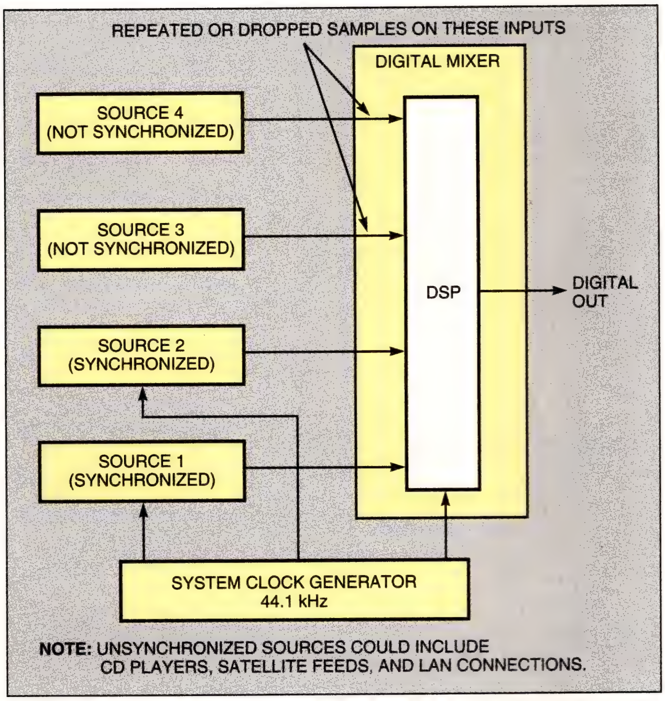
REPEATED OR DROPPED SAMPLES ON THESE INPUTS
DIGITAL MIXER
SOURCE 4 (NOT SYNCHRONIZED)
SOURCE 3 (NOT SYNCHRONIZED)
SOURCE 2 (SYNCHRONIZED)
SOURCE 1 (SYNCHRONIZED)
DSP
DIGITAL OUT
SYSTEM CLOCK GENERATOR 44.1 kHz
NOTE: UNSYNCHRONIZED SOURCES COULD INCLUDE CD PLAYERS, SATELLITE FEEDS, AND LAN CONNECTIONS.

Fig 2—In this digital mixer with "wild" feeds, the unsynchronized sources could include CD or digital audio-tape players, satellite feeds, LAN connections, and other sampled-data systems. Because the unsynchronized sources can not operate in slave mode, repeated or dropped samples are inevitable.

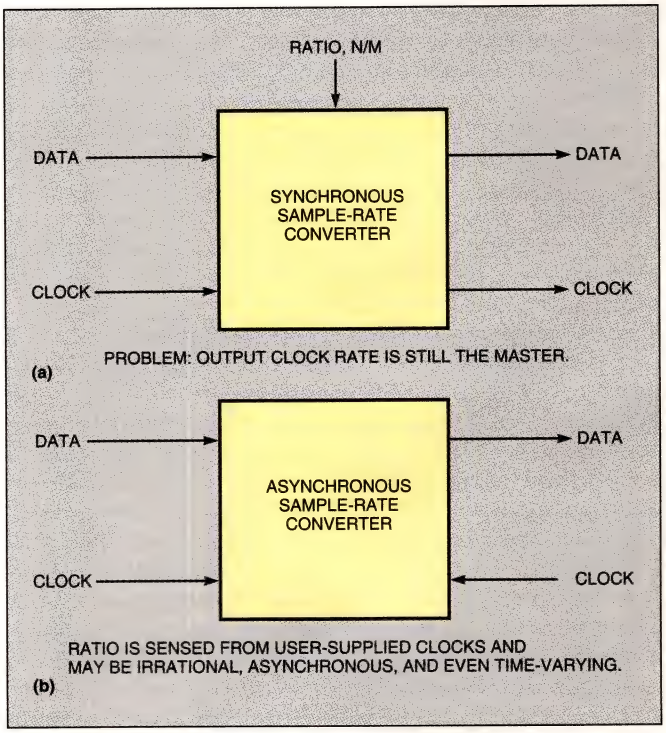
RATIO, N/M
DATA
DATA
SYNCHRONOUS SAMPLE-RATE CONVERTER
CLOCK
CLOCK
PROBLEM: OUTPUT CLOCK RATE IS STILL THE MASTER.
(a)
DATA
DATA
ASYNCHRONOUS SAMPLE-RATE CONVERTER
CLOCK
CLOCK
RATIO IS SENSED FROM USER-SUPPLIED CLOCKS AND MAY BE IRRATIONAL, ASYNCHRONOUS, AND EVEN TIME-VARYING.
(b)

Fig 3—In a synchronous sample-rate conversion system (a), the user sets the frequency ratio explicitly to a rational number; in an asynchronous system (b), the ratio is sensed from user-supplied clocks and can be irrational, asynchronous, and even time-varying.

the filter coefficients to be used in the calculation of any output sample. This observation leads to the "polyphase-filter" model, in which the filter coefficients split into n separate FIR filters (**Fig 7**). Each "tick" of the input clock produces four simultaneous outputs. These values are then read out sequentially at the rate $FS_{in} \times N$, resulting in the same sequence of output values as that of the original interpolation filter.

Because each subfilter uses the same stored input data, you can store this input data only once in a common RAM. This technique reduces the required amount of RAM because you do not need to store the zeros that were conceptually inserted in the interpolation. Also, the computation rate goes down becase the digital filter's multiply-accumulate automatically skips zero-valued stored data values.

An obvious simplification of this technique is to compute only those outputs that decimation does not discard. You can use a simple formula to select the correct polyphase-filter branch for each requested output. To produce the Kth output sample, the branch index Bk is Bk=KM mod N.

An integrator that advances by M every time an output is computed, with a modulus of N can produce the branch-selection index. You can then simplify conversion to an FIR filter with N sets of coefficients, where you choose the correct set of coefficients each output sample according to the above equation.

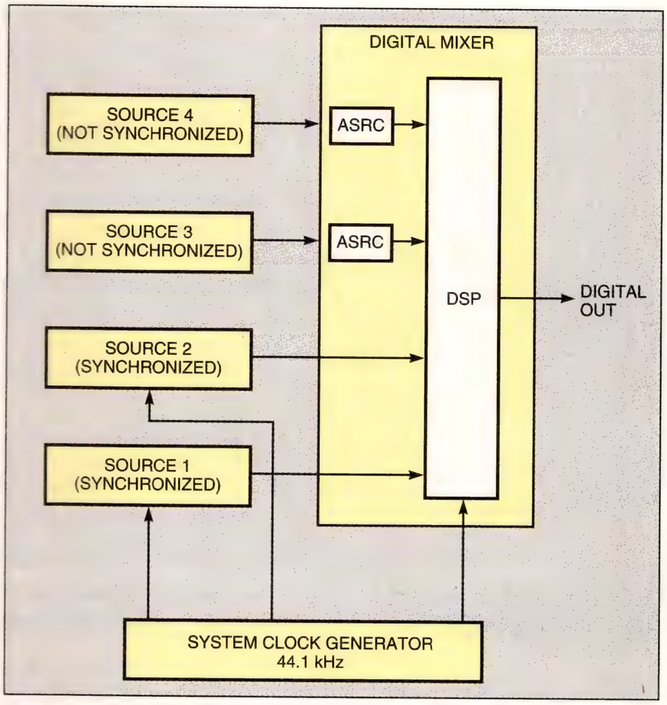
DIGITAL MIXER
SOURCE 4 (NOT SYNCHRONIZED)
ASRC
SOURCE 3 (NOT SYNCHRONIZED)
ASRC
DSP
DIGITAL OUT
SOURCE 2 (SYNCHRONIZED)
SOURCE 1 (SYNCHRONIZED)
SYSTEM CLOCK GENERATOR 44.1 kHz

Fig 4—The ASRCs in the unsynchronized channels solve the problem of dropped or repeated samples inherent in the wild-feed system of Fig 2. The input clock to each ASRC is derived from the serial input stream of each channel, using a PLL.

Asynchronous sample-rate-conversion theory

You can extend the described interpolation/decimation model to asynchronous conversion by simply making the interpolation ratio extremely large (**Fig 8**). As the interpolation ratio increases, the correlation between adjacent interpolated output samples becomes so high that the

POPULAR AUDIO SAMPLING RATES AND APPLICATIONS

Sampling frequency	Application (kHz)
44.1	CD, DCC, digital audio tape
32	DCC, digital audio tape, MAC, NICAM, DSR
48	Professional audio, digital audio tape, DCC, DAB, S-VHS
16	MAC
18.9	CD-I (Level C)
37.8	CD-I (Levels A and B)
31.5	8-mm videocassette recording
44.056	U-matic videocassette recording
38	Digital FM-stereo decoders

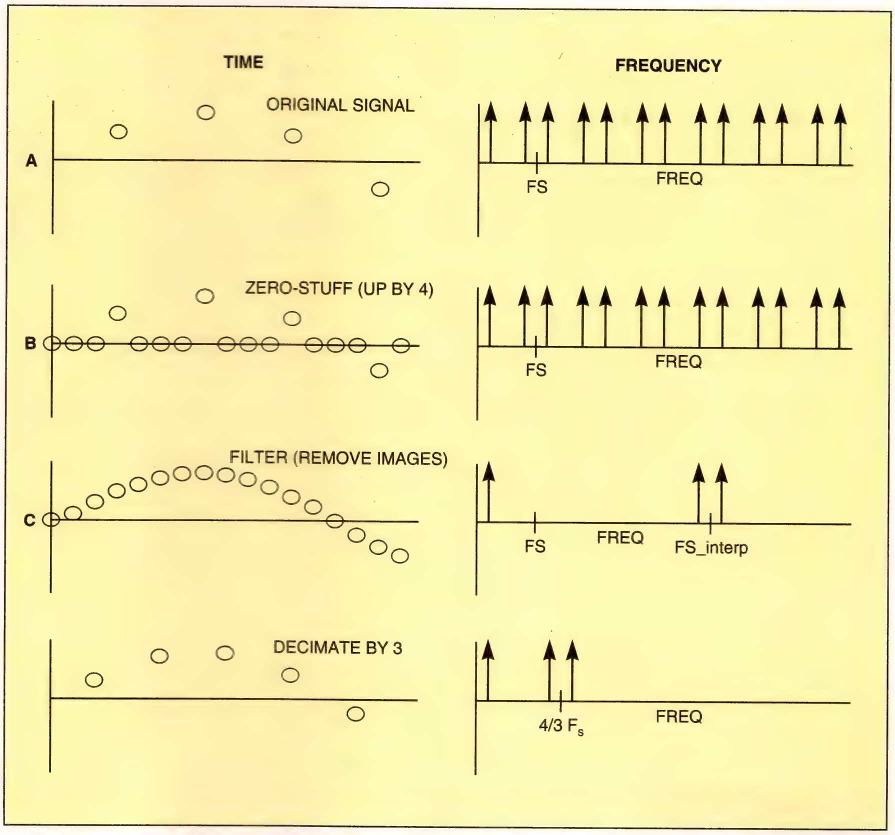

Fig 5—This synchronous sample-rate conversion example uses an N/M ratio of 4/3. It reconstructs the input signal through interpolation by four, digital filtering, then decimation by three.

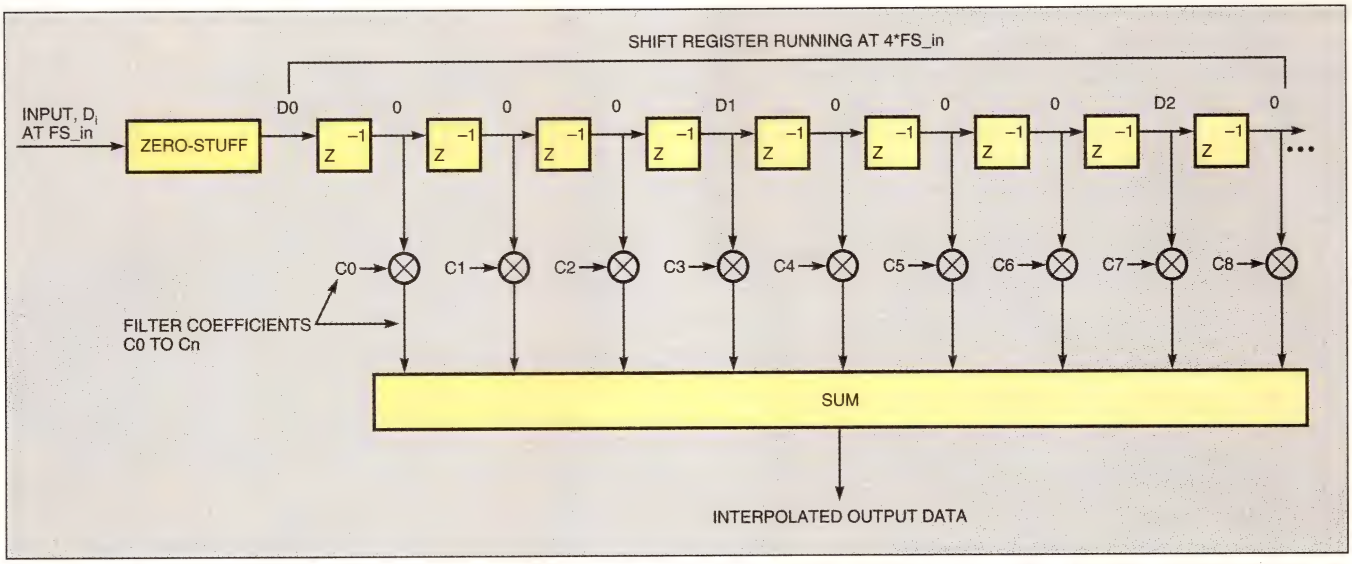

Fig 6—This hardware model for effecting an interpolation by four uses a shift register running at four times the input clock frequency. The zero-stuffing operation causes only a subset of the filter coefficients to be used in the calculation of any output sample.

worst-case change between one interpolated sample and the next is smaller than an LSB of the desired output word length. The resampling simply grabs the "nearest" interpolated output when the user-supplied output clock requests an output sample.

By using such a high interpolation ratio, the interpolated signal resembles an analog signal for all practical purposes, and the resampling process at the new output rate is no different from sampling the original analog signal at the new rate.

To achieve 16-bit worst-case performance, you must use an intepolation ratio of 65,536. You must use the polyphase-filter hardware-reduction techniques to avoid a huge computation rate. The length of each polyphase filter does not increase with the interpolation ratio, but the number of parallel polyphase-filter branches becomes very large for high-quality interpolation. For example, the AD1890 single-chip ASRC (see **box**, "A silicon solution for ASRC") uses 65,536 sets of polyphase filters, each with 64 coefficients. The IC uses a compression technique to reduce the required internal ROM to store these coefficients and uses on-the-fly decompression hardware during multiply/accumulate.

Previously, we saw how you can generate a sequence of polyphase branch indexes in the synchronous case where N and M are explicitly given. In the asynchronous case, you must generate the sequence of polyphase branch-index numbers based on measurements of the relative phases of the user-supplied input and output clocks. In theory, you can directly measure clock-arrival times, but this implies that a high-

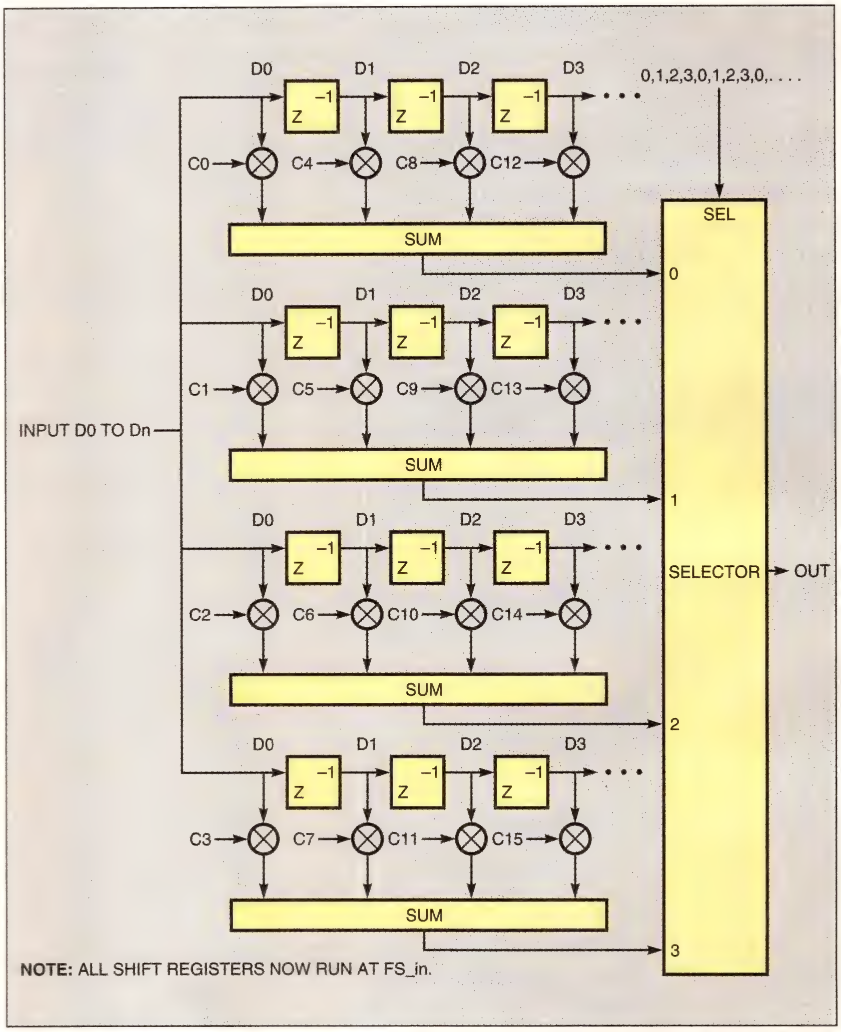

Fig 7—In this polyphase-filter model, the filter coefficients are split into N separate FIR filters. This configuration reduces the amount of RAM required because as the zeros that were conceptually inserted in interpolation do not need to be explicitly stored.

A SILICON SOLUTION FOR ASRC

In the past, solutions for asynchronous sample-rate conversion have used multiple DSP chips along with external dedicated hardware, often using very high-frequency clocks to measure the arrival times of external clocks to high accuracy. These solutions often carry prices exceeding $5000. As a result, system designers were often obliged to live with the problem of occasional dropped or repeated samples or in some cases had to go through an extra stage of A/D to D/A conversion.

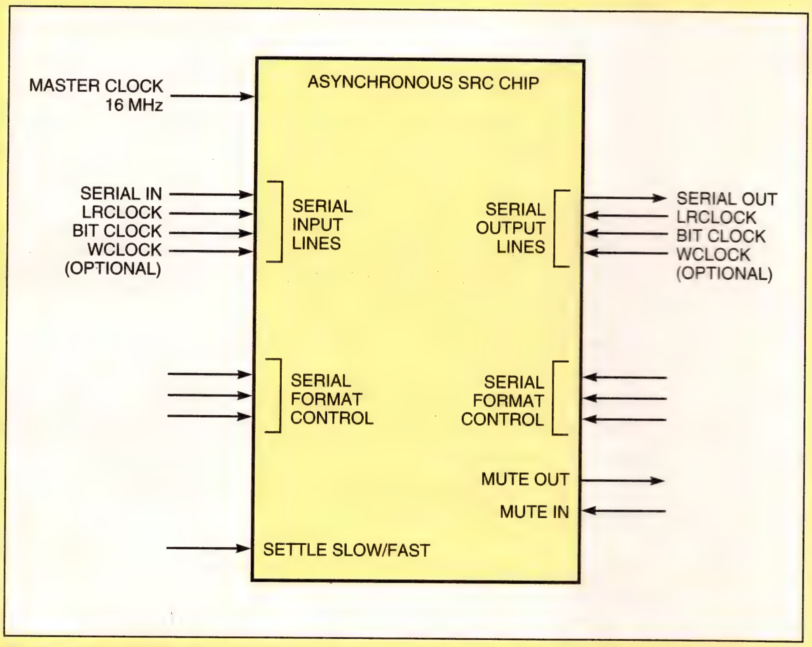

Fig A—This ASRC chip eliminates the need for multiple DSP chips and other dedicated hardware; moreover, its serial input, output, and interface lines simplify system design.

All-digital monolithic ICs that implement a complete stereo, asynchronous sample-rate converter are now available. The AD1890 is the first such chip to enter the field. While quite complex on the inside, the chip is very easy to use from the designer's perspective (**Fig A**). Input data comes in serial form to the device, using a simple 3-wire interface. The L/R clock acts as the frame sync; it indicates the start of a serial word, as well as whether the received data is for the left or right channel. This signal is used internally to sense the input sample rate.

The output signal also appears in serial form. The framing signal for the output L/R clock is an input to the chip. Again, this represents the difference between synchronous and asynchronous converters—an asynchronous converter accepts an external sample-rate clock as an input to the device and produces data on demand. The chip requires a master clock with a 16- to 20-MHz frequency for proper operation. It's not necessary to synchronize this clock to either the input or the output sample frequencies. The input word length is 20 bits, which easily accommodates digital audio signals from most professional equipment. Word lengths as great as 24 bits are available at the output.

The AD1890 follows real-time variations in the input or output sample frequencies with no error. The chip features a programmable acquisition time: In "fast" mode, the device rapidly tracks large step changes in the input or output sample frequencies, and in "slow" mode, it tracks only gradual variations. One advantage inherent in the slow mode is that jitter in either the input or the output L/R clock is heavily filtered, allowing accurate rate conversion even in the presence of large amounts of clock jitter.

In slow mode, the device attenuates jitter frequencies above 3 Hz by 6 dB/octave. This feature is important in systems in which the clock must be recovered from the serial input stream. In many cases, the high-frequency losses that occur when serial data is sent over long cables result in intersymbol interference in the data stream. When recovering a clock signal from such a signal (using a PLL), large amounts of jitter may occur in the recovered clock. This jitter can cause excess noise and distortion if you use the jittery clock to clock a D/A converter. By allowing a crystal-generated local clock to 2establish a stable internal clock, you can avoid this type of degeneration.

Fig B shows the IC's performance in signal quality. When converting from 48 to 44.1 kHz (two common audio rates), the THD plus noise (THD+N) is greater than −105 dB. For any sample-rate converter, the worst-case input signal is a full-scale signal at the band edge. For a 20-kHz, full-scale input signal, the THD+N degrades to −95 dB, or 16-bit equivalent quality. These distortion products scale with the input level: If you reduce the input by 20 dB, the distortion components decrease by 20 dB as well.

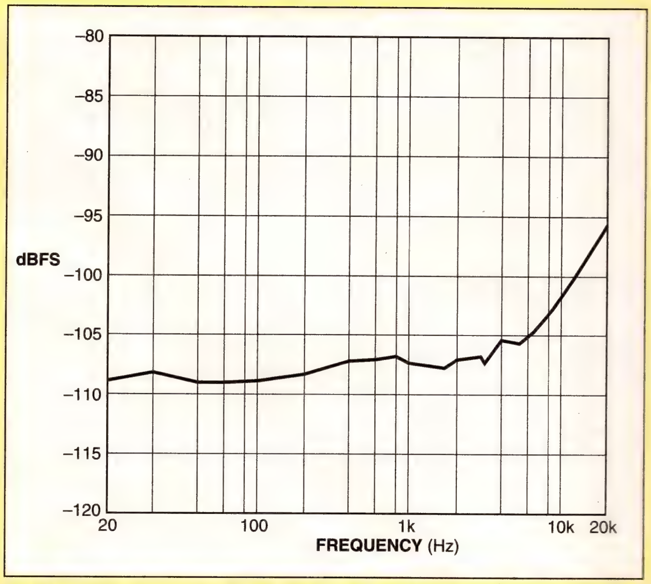

Fig B—THD plus noise (THD+N) for the AD1890 ASRC chip is about −96 dB (16-bit equivalent quality) in the worst-case scenario: a full-scale, 20-kHz input.

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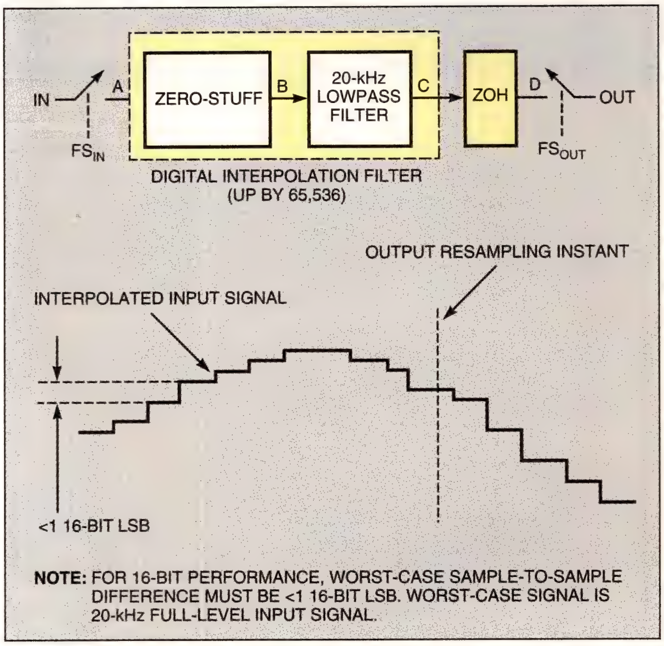
IN
A
FS$_{IN}$
ZERO-STUFF
B
20-kHz LOWPASS FILTER
C
ZOH
D
OUT
FS$_{OUT}$
DIGITAL INTERPOLATION FILTER (UP BY 65,536)
OUTPUT RESAMPLING INSTANT
INTERPOLATED INPUT SIGNAL
<1 16-BIT LSB

NOTE: FOR 16-BIT PERFORMANCE, WORST-CASE SAMPLE-TO-SAMPLE DIFFERENCE MUST BE <1 16-BIT LSB. WORST-CASE SIGNAL IS 20-kHz FULL-LEVEL INPUT SIGNAL.

Fig 8—You can extend the interpolation/decimation model for synchronous conversion to asynchronous conversion by simply making the interpolation ratio extremely large. As the interpolation ratio increases, the correlation between adjacent interpolated output samples becomes so high that the worst-case change between one interpolated sample and the next is smaller than an LSB of the desired output word length.

frequency several-gigahertz clock signal is available to achieve the required measurement accuracy.

The AD1890 ASRC chip eliminates this requirement by digitally filtering a series of low-accuracy clock-arrival measurements. The process results in better than 200-psec time resolution, even though the master clock runs at only 16 MHz. In addition, the low cutoff frequency (less than 3 Hz) effectively rejects jitter on the user-supplied input and output clocks.

When the sample rates are dynamically changing, the digitally filtered internal estimate of the input/output relative clock phases may lag behind the actual external-clock phases because of the low cutoff frequency of the digital filter. You could use extra RAM as an elastic store buffer in this case, allowing the ASRC to track dynamically changing sample rates without error. EDN

Author's biography

Robert Adams is manager of audio development at Analog Devices Inc, where he's worked for five years. His principal duty is to design ICs for the multimedia, consumer, and professional-audio markets. A member of the IEEE and a Fellow in the Audio Engineering Society, Robert has a BSEE degree from Tufts University, Medford, MA. His spare-time pursuits include family activities and playing the saxophone in a jazz band.

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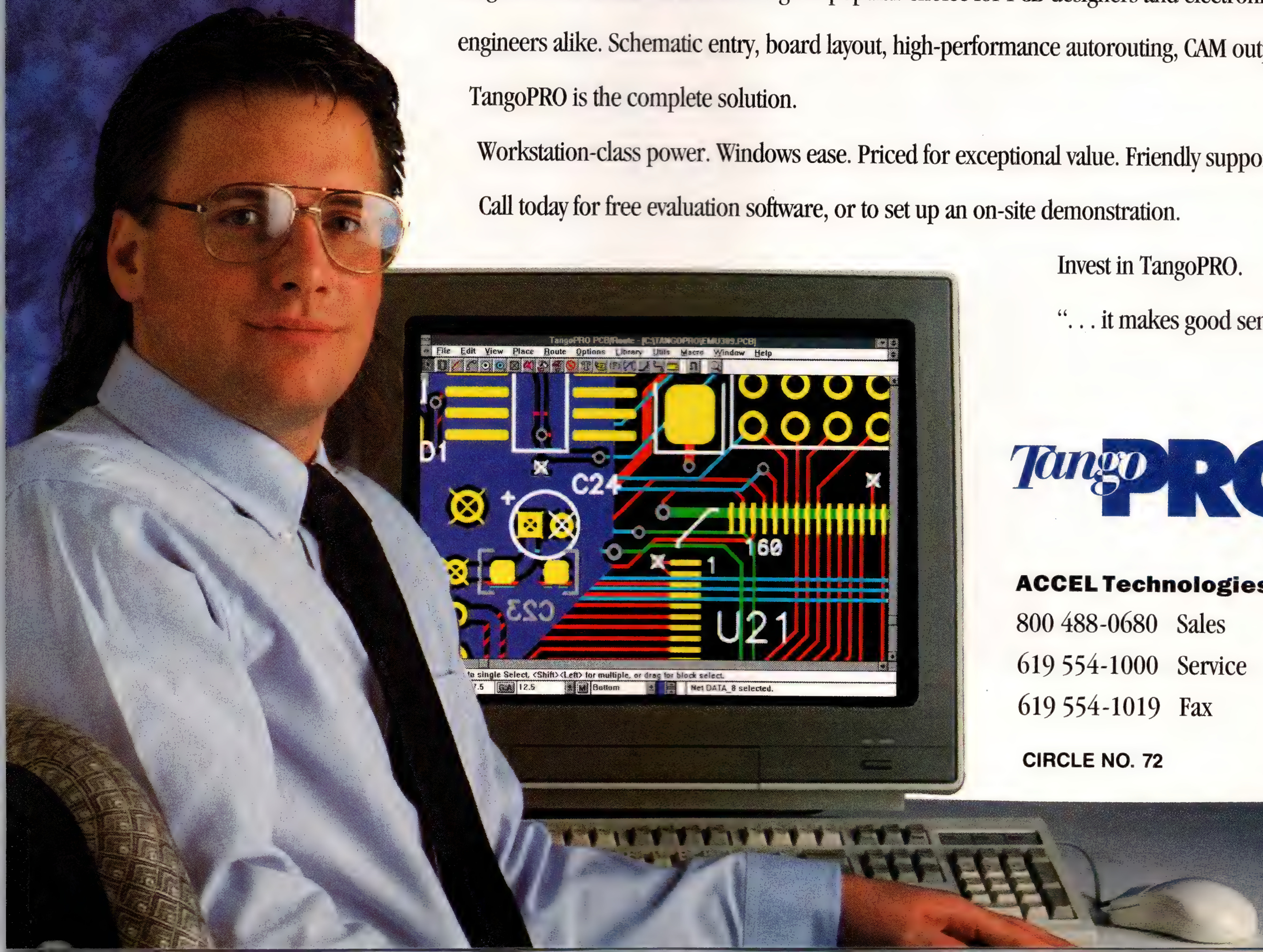
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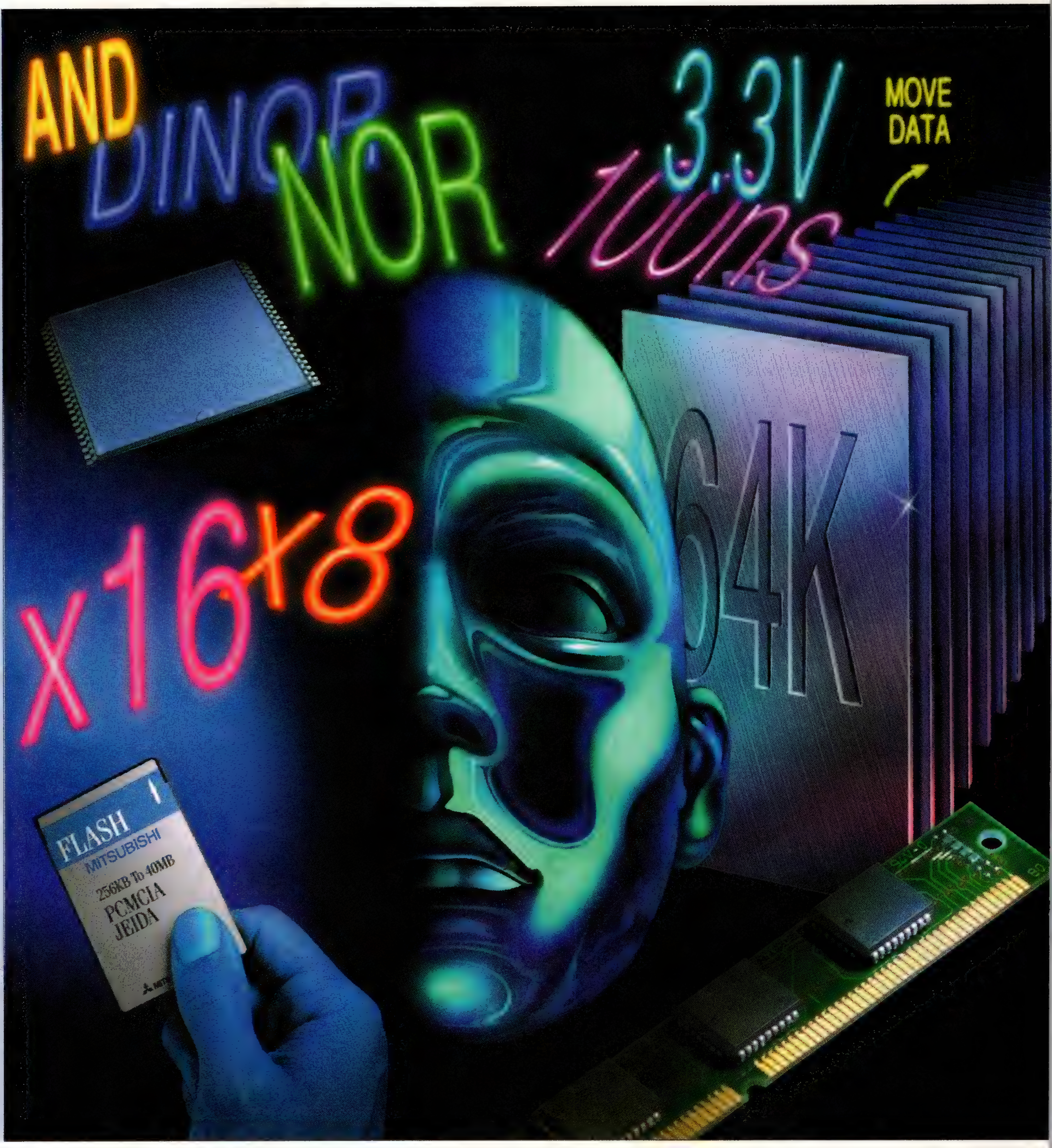

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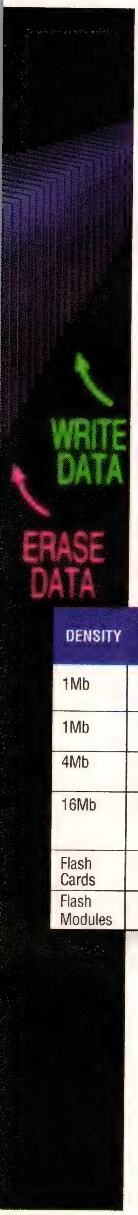

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1Mb	64K x 16	Bulk Array	$5V/12V_{pp}$	100, 120, 150	SOP, PLCC, TSOP	10K/100K	Wordwide Architecture Reduces Chip Count; Socket Compatible With x16 EPROMs/OTP ROMs; Industrial Temp. Range (150ns)
4Mb	512K x 8 / 256K x 16 (User Selectable)	32 Sym. Blocks, 16KB/8K Word each	$5V/12V_{pp}$	100, 120, 150	SOP, TSOP	10K	Small Block Size Optimized for Code/Data Storage Applications; Automatic Program/Erase
16Mb	2M x 8	32 Sym. Blocks, 64KB each	$3.3V/12V_{pp}$	100, 120, 150	SOP, TSOP	10K/100K	Easy Upgrade from Industry-Standard 8MB Flash Designs; 100ns Access Time at 3.3V; Deep Power Down (0.5µA); Automatic Program/Erase
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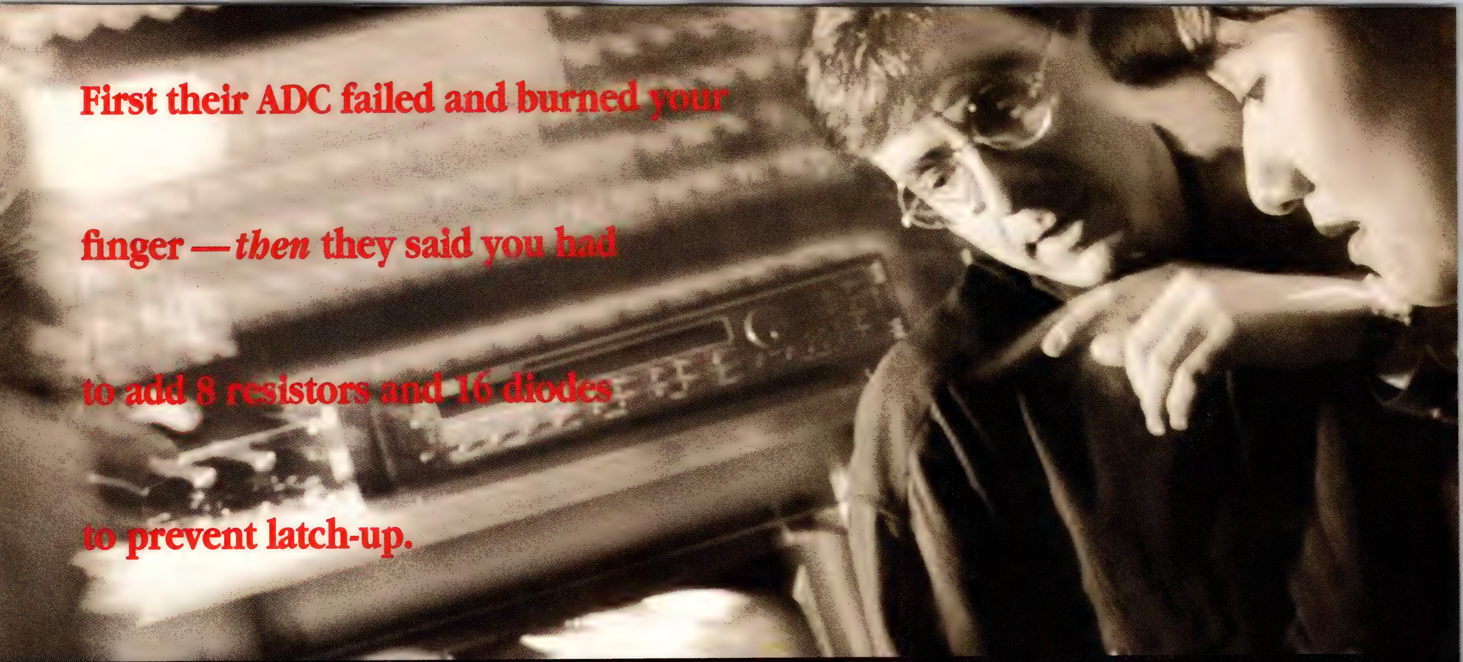

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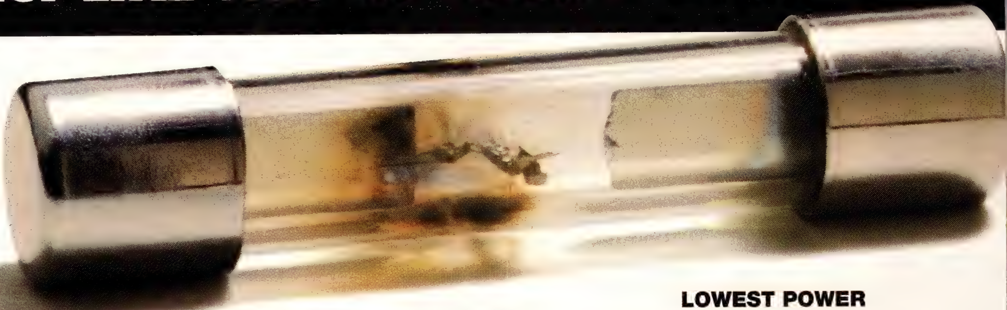

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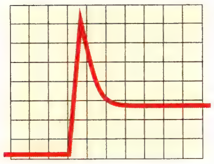

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Electromagnetic theory imposes constraints on pc-board design

Gregory S Seltzer, Mentor Graphics Corp, and Reza Ahy and Monica Razmi, Stanford-Berkeley Associates

An understanding of electromagnetic effects often leads to a better pc-board design than prototyping and debugging in the lab using traditional rules of thumb.

Many board designers still rely heavily on prototyping boards and debugging them in the lab, using traditional rules of thumb (See **box**, "Modern high-speed design"). However, today's increasingly complex products feature high-speed signals that introduce new types of timing errors. It's becoming difficult, if not impossible, to detect, locate, and fix all board-level timing problems on a prototype within tight design schedules. The only way to manage high-speed timing effects is to anticipate them using electromagnetic theory, to include them in your timing scheme, and to budget for them in your layout.

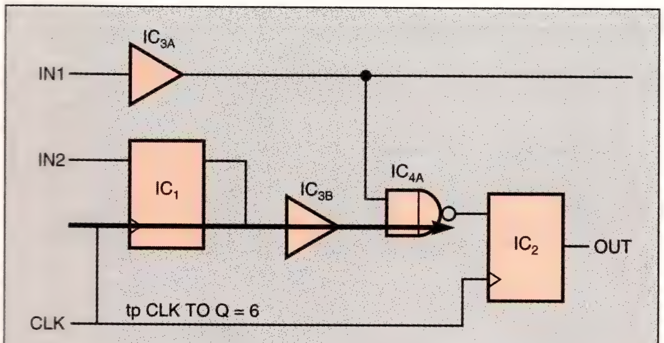
The problems associated with high-speed design are forcing designers to rethink their design approaches. Mike Williams of Hewlett-Packard (**Ref 1**), states "The system ran correctly at 95% of full speed but failed randomly at higher speeds. The failure location and symptoms differed for each occurrence. Analysis showed that some segment delays were slightly longer than the timing scheme and cycle time allowed." These problems are typical of designs in which the interconnects don't have enough design margin to accommodate timing variations. Such variations stem from component timing tolerances, process variables, interconnect and packaging delays, and other electrical effects.

Beyond ensuring product functionality, considering high-speed effects early in the design cycle can produce additional benefits. In **Ref 2**, a designer describes a feasibility study for upgrading a 50-MHz, 486-based board to 100 MHz. With the layout, the designer had to upgrade his 7-nsec SRAMs to significantly more expensive 6-nsec units. After closer evaluation, the designer constrained the physical layout to halve the skew and time-of-flight delay. This layout allowed him to use the slower and less expensive SRAMs and still meet the tighter timing requirements with sufficient design margin.

Designing for high-speed effects doesn't eliminate the need for probing; electrical and physical measurement techniques are important for characterizing the behavior of your interconnect before design. This characterization can enable you to predict high-speed effects so that you can allocate them in your budget. **Ref 3** discusses TDR and TDT measurements of interconnect timing effects.

Start with a budget

The first step is to perform a detailed timing analysis to determine your design margin. This procedure could include a critical-path analysis that identifies slack time for setup-and-hold constraints. You then assign priorities to these



ELEMENT	DELAY(NSEC)
(IC$_1$)tp TO CLK TO Q	4
BUFFER	3.2
NAND	3.2
(IC$_2$) SETUP TIME	1.2
TOTAL	11.6

SLACK TIME=15-NSEC CLOCK CYCLE – 11.6 NSEC = 3.4 NSEC

Fig 1—This simple design example shows how to evaluate slack time for a critical-path analysis.

paths, basing the priorities on how critical the paths are in the system design.

You must then allocate part of your design margin to physical-interconnect delay and electrical behavior. These interconnect effects can have many sources. For example, if your interconnect behaves like a transmission line, then you must consider speed-of-light and distortion delays, and you must analyze the potential effects of skew, jitter, and pulse-width shrinkage and growth. You must then allocate a budget for these physical effects and constrain the layout to stay within this budget.

As a simple example, **Fig 1** illustrates a basic path analysis for a logic circuit with a 66-MHz clock. If you analyze strictly the intrinsic delay of the devices, you can determine the available slack for the setup constraint on IC_2. It takes 4 nsec for the data to propagate through IC_1. If you add the delay through the combinatorial logic, the data arrives in 10.3 nsec. If the next positive clock edge arrives 15 nsec after the first edge, and you have a 1.2-nsec min setup requirement, then you end up with 3.4 nsec of available slack time.

The critical-path analysis for the setup condition compares the slowest data path with the fastest clock path under worst-case parameters for the intrinsic timing of the devices. This 3.4 nsec doesn't accurately represent your design margin. You should allocate at least 50% of this slack time to interconnect effects, such as skew, speed-of-light delay, and distortion delay.

When is high speed an issue?

You must analyze and control "high-speed" effects in your overall design so that you can make intelligent tradeoffs when it's still economically viable to alter the design and layout.The obvious questions are: When is a design considered a high-speed design, and when should you worry about high-speed design problems?

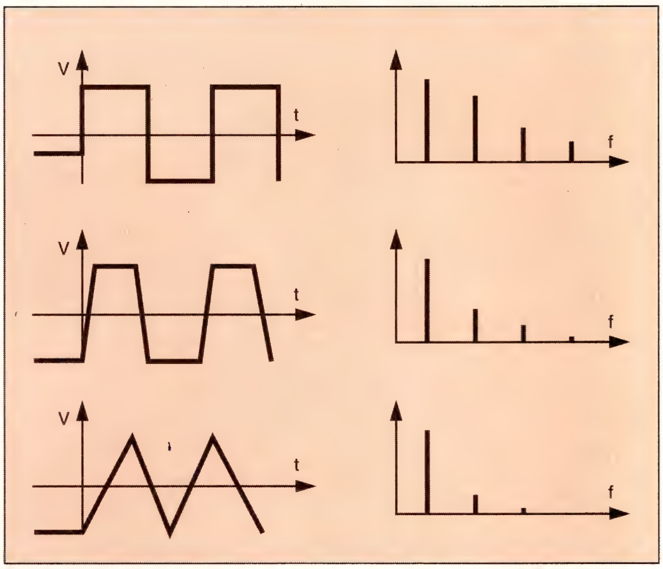


Fig 2—Various pulse shapes in the time domain exhibit different frequency contents, both in number of harmonics and in magnitude, in the frequency domain.

The answers depend on the problem. The simplest definition of a high-speed signal path is "a path in which the wavelength of the signal begins to approach the physical dimensions of the interconnect." When this scenario occurs, you can expect to encounter problems you previously could have ignored.

Some relate the term "high speed" to the clock frequency of the design. Although that is a leading indicator, the actual clock frequency does not cause the problems in high-speed design. Instead, the clock frequency determines the amount of time in which operations must complete. As this window becomes smaller, every picosecond becomes precious.

According to market surveys, more than 50% of new board designs worldwide use clock frequencies of 50 MHz or greater. When Intel introduced its Pentium processor, 66 MHz became a new standard clock frequency. A 66-MHz clock frequency represents an equivalent clock period of 15 nsec. For a 50% duty cycle, only 7.5 nsec is available for two transitions and the pulse width. Therefore, designers must use technologies with rise times of 2 nsec or less.

Rise time is the most critical factor in determining when an interconnect will exhibit high-speed effects. The digital signal has frequency components at the harmonics of the clock frequency (**Fig 2**). As the rise time decreases, the bandwidth of the signal naturally increases. The bandwidth of a digital signal is its frequency spectrum of importance; that is, dc to the highest harmonic of the clock frequency necessary to preserve a prescribed rise time. The relationship between rise time and bandwidth gives a more accurate idea of when to treat an interconnect as a transmission line, than do the traditional rules of thumb.

For proper logic operation, a digital signal needs a minimum pulse width with a monotonic edge, whose signal shape approximates a pulse without significant ringing. If the signal propagates down a transmission line, any discontinuity would reflect part of the signal's energy and, therefore, distort the signal. If the rise time is fairly long, then the rising signal could damp out the reflected wave. If the rise time is

$$L_{CRITICAL} = \frac{c}{\sqrt{\varepsilon_r}} \cdot \frac{t_r}{7} = \frac{V_{PROP} \cdot t_r}{7}$$

FAMILIES	RISE TIMES (NSEC)	CRITICAL LENGTH (IN.)
AS	1.9	1.60
BiCMOS	0.7	0.59
ECL	0.5	0.42
GaAs	0.3	0.25

Fig 3—The equation expresses the critical length of a trace, the length at which the trace must be considered as a transmission line. This length is a function of the rise time, as shown in the table relating critical length to various logic families.

short, then these reflections would distort the driving signal and degrade the signal quality.

You can prevent an interconnect from behaving as a transmission line. To do so, you must evaluate the switching characteristics of the driver to determine the length at which the interconnect would behave as a transmission line. The sharper the rise time, the greater the frequency components generated. The frequency components, or the "signal bandwidth," calculated by 0.35/tr. The equation in **Fig 3** gives the "critical length," or the length at which you must consider the interconnect must be a transmission line.

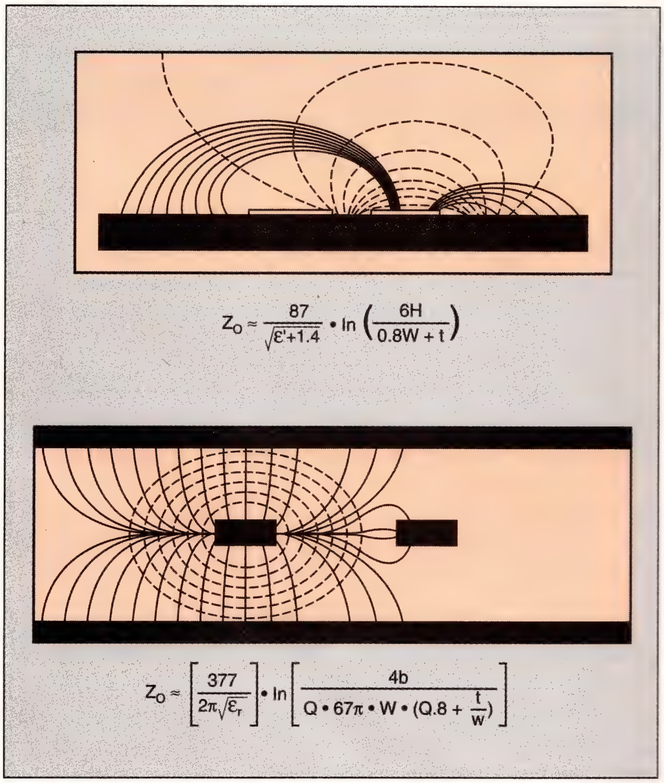
For example, a 1-nsec edge would have a bandwidth of 350 nsec. In a strip-line configuration using pc-board material with a dielectric constant of 4, the wavelength is 42.86 cm at a bandwidth of 350 MHz. Therefore, the critical length is approximately 2.2 cm. **Fig 3** gives an idea of how critical lengths relate to various technology families.

If you must consider the interconnect as a transmission line, then you need to have a good understanding of transmission-line theory. Based on electromagnetic theory, transmission-line theory was developed to transmit power over long distances. A signal in a pc-board trace creates an electromagnetic wave that travels at a given velocity. The velocity depends on the electrical properties of the pc-board material: its dielectric constant (permittivity) and its magnetic constant (permeability).

The impedance of that trace—that is, its resistance to the flow of energy—depends on the physical construction of the board and the electrical characteristics of the traces and the material surrounding them. If a sudden change in impedance occurs, then part of the signal's energy reflects back. The reflected signal energy could potentially disturb the signal transmission from the driver to the receiver.

You can minimize these reflections by controlling the sources that cause changes in impedance. Such changes in the electrical characteristics of the interconnect result from changes in the physical construction of the interconnect: You could change the layer, the trace width, the branch stub, the bond wire, or the connector. You can design the physical interconnect such that these changes do not cause significant changes in impedance. **Fig 4** shows how the impedance of a trace depends on the trace width, conductor thickness, and pc-board material in a microstrip or strip-line configuration.

You can design different trace widths per layer to obtain impedance matching. You can also use termination techniques to try to match the impedance of the interconnect to that of the load or source. However, impedance mismatch is inevitable, especially with logic devices that have different impedances, depending on their logic state. For high-speed digital design, you must understand the effects of this reflected signal energy and determine the sensitivity of your design to the resulting distortion.



$$Z_O \approx \frac{87}{\sqrt{\varepsilon' + 1.4}} \bullet \ln\left(\frac{6H}{0.8W + t}\right)$$

$$Z_O \approx \left[\frac{377}{2\pi\sqrt{\varepsilon_r}}\right] \bullet \ln\left[\frac{4b}{Q \bullet 67\pi \bullet W \bullet (Q.8 + \frac{t}{w})}\right]$$

Fig 4—The impedance of a trace depends on the trace width, conductor thickness, and the pc-board material in a microstrip or strip-line configuration. In short, it's a function of the physical dimensions and the electrical characteristics of the material surrounding the interconnect.

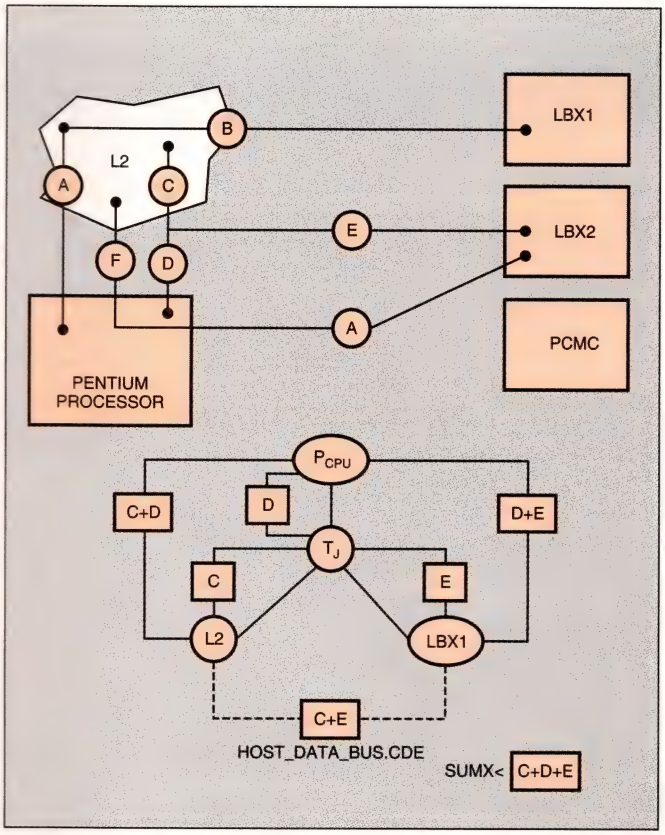


Fig 5—Intel defines this topology in the EZ Layout Guidelines for the host data bus. This topology comes from Intel's Pentium Open Design Guideline program.

ELECTROMAGNETIC THEORY

Consider, for example, Intel's approach in developing guidelines for board designers using the PCI specification. In evaluating the worst-case loading for this spec, Intel engineers faced the conflicting problems of maximizing the routing density while minimizing thermal and signal-integrity constraints. To meet the timing requirements, they had to manage the problem of the interconnect's acting as a transmission line.

If they had used termination techniques, then the board density and thermal dissipation would become worse. Instead, they developed test boards to measure and characterize the interconnect, then performed more than 3000 hours of interconnect simulation. Their conclusion: If they allowed the interconnects to switch on the reflected wave, then they could avoid using termination techniques and still meet timing and signal-integrity objectives.

To document their recommendations, the Intel engineers created guidelines that suggest layout topologies and topology rules. A layout topology is a constraint that requires you to order the physical pins according to a specified definition. For example, a daisy-chain ordering first routes the drivers, then sequentially routes the loads, then routes a terminator after the last load. To meet flight-time constraints while minimizing skew requirements, Intel specified for the Pentium-processor, Mercury-motherboard design some topologies that require the user to include branches or non-daisy-chain topologies. **Fig 5** shows an example of a topology that Intel defines in the EZ Layout Guidelines for the host data bus.

The ogre of induced crosstalk

Faraday's law of induction states that current in one conductor can induce current in another conductor. This coupling of energy between traces increases significantly as the separation between the traces decreases and the interconnect density increases. As a wave propagates down a trace, the wave couples energy to adjacent traces via mutual capacitance and inductance. The mutual capacitance induces voltage in an adjacent trace forward and backward. Mutual inductance induces a current in an adjacent trace. From these induced signals, you can measure forward (far-end) and backward (near-end) crosstalk.

To understand how crosstalk affects a signal, imagine that the active pulse is a truck filled with sand and that the passive trace is a conveyor belt moving at the same speed as the truck. The noise accumulated on the conveyor belt depends on the rate at which the sand falls from the truck and on the distance the truck travels parallel to the belt. The noise induced in the passive line is proportional to the amount and length of the coupling. It is also proportional to the difference between the mutual capacitance and inductance and inversely proportional to the rise time.

To reduce forward crosstalk, you can reduce the amount of coupling by limiting the parallelism between traces or by using logic with the slowest possible rise time. Alternatively, you can bury the traces in a strip-line configuration in which the capacitive and inductive coupling are equal; thus, the forward crosstalk is negligible.

MODERN HIGH-SPEED DESIGN

The 1990s are witnessing an explosion in performance, thanks to continuing advances in μP technology. Significant increases in design complexity have accompanied these advances. Yesterday's digital designer could reduce the real world to simple logic. Today and in the future, the same digital designer will have to face the realities of a more complex analog world. The transmission-line effects that appear at faster edge rates can wreak havoc in a logic design that once worked perfectly at lower speeds.

Designers in the past have relied on rules of thumb that have been passed down in the same way a craftsman passes his trade to an apprentice. Unfortunately, these rules of thumb can lead a designer down the wrong path. Rules of thumb have developed over time to solve specific problems under certain sets of circumstances. As time passes, the rules live on, but the rationale behind the rules is long forgotten. Designers can thus make decisions that might not be optimal for a new set of constraints and design complexities.

The only way to make intelligent design decisions is to have a good understanding of problems related to high speed. When you understand the electromagnetic theory behind the high-speed phenomenon, you can determine which effects to be concerned with and what causes these effects. Through understanding the effects, you can make better design tradeoffs to optimize your overall design.

You must be able to reconcile conflicting requirements. Product complexities are increasing, and the market has become extremely competitive. It is not enough to design a product that simply meets the performance requirements. You have to compete on time-to-market, cost, quality, and performance. You must therefore consider the impact of your design decisions. Often, one solution to a problem can introduce new problems. For example, you may be able to avoid a transmission-line problem by making traces as short as possible. The increase in density, however, can easily result in a board that can't be routed without adding extra layers or a board that exceeds thermal budgets.

By understanding the behavior of high-speed signals, you can also avoid the cost and effort that ensue from overly conservative designs. Just because a trace might act as a transmission line doesn't necessarily mean it will introduce errors. If you analyze the switching effects of the reflected wave, it's possible the line will not need termination and the timing integrity will still be within specification.

While silicon once limited system performance, today's limiting factors are the interconnect and package delays and other electrical effects related to timing, such as skew, jitter, and pulse-width shrinkage and growth. Today's design tools can give you the ability to verify logic and to predict the high-speed effects that are likely to appear in the fabricated product.

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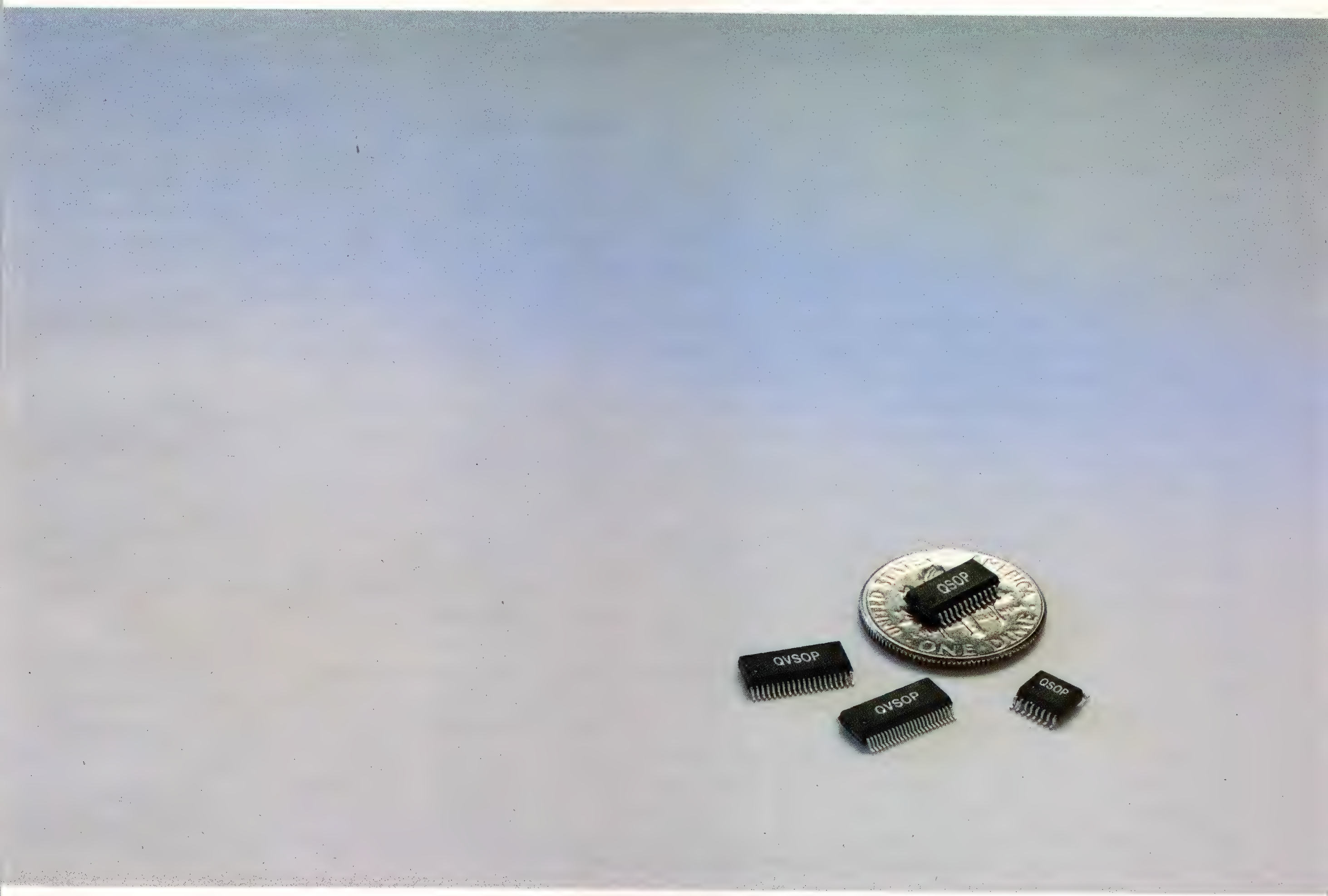

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CIRCLE NO. 34

ELECTROMAGNETIC THEORY

For backward crosstalk, envision the passive trace as a conveyor belt that travels in the opposite direction from that of the truck and measures twice as long as the truck. The noise induced in the passive line does not depend on the coupling length but instead is proportional to the signal velocity. The noise has twice the duration of the propagation delay of the active trace, and it is proportional to the sum of the capacitive and inductive coupling. You can minimize the backward crosstalk by designing larger separations between traces.

Fighting the perils of ground bounce

Another source of noise appears when multiple lines switch simultaneously, especially in systems using CMOS technology. Devices that switch very quickly may try to sink current from many I/O pins through common power and ground pins. The resulting current surge through the pins' impedance can create a voltage drop, which appears as noise on the output signals.

Ref 4 states, "An HCMOS bus with an ac termination of 70 pF and 60Ω on each end does a terrific job of limiting reflections. But if all 64 bits switch simultaneously, almost 180 mA of ground current will be generated for each data line, for a total of 11A. Even with good grounding practices, these small inductances in the ground system can cause large glitches." The designer in this example halved the current by reducing the terminating resistive load.

You can try to minimize ground bounce by providing a low-inductance path to ground. To do this, you must pay attention to the placement and routing of power and ground traces. Another approach is to use SSOPs. These packages provide twice the number of pins per area as an SOIC package. You can allocate the extra pins to form additional power and ground leads, thereby reducing the inductive path to ground and lessening ground bounce.

The old rules of thumb in pc-board design have limited applicability as technology advances in speed, performance, and density. In today's competitive market, only companies that can manage this increased complexity in a timely manner will survive. Design teams that can optimize tradeoffs between conflicting requirements will have an advantage. That advantage takes the form of a greater understanding of high-speed problems.

This in-depth understanding allows you to take advantage of new tools and technologies that can help you to predict and to prevent high-speed problems. For example, electronic-design-automation and IC manufacturers have adopted an I/O-buffer information specification that will standardize the development of models for signal-integrity analysis. Such up-front analysis, combined with timing-driven placement and routing tools, will make it easier to manage high-speed effects in your pc-board design. EDN

References

1. Williams, Mike, "Timing Considerations in Clock Distribution Networks," Application Note 1210-10, Hewlett-Packard Co, San Jose, CA.

2. Smith, Kaufman, and Frazier, "Doubling the Clock Speeds: Feasibility Study on a 486 50-MHz Cache Module at 100 MHz," High-Speed Digital Design Symposium, Hewlett-Packard Co, San Jose, CA.

3. Strassberg, Dan, "In >50-MHz digital design, measurements are a must," *EDN*, August 19, 1993, pg 65.

4. Cutler, Robert, "Your logic simulation is only as good as your board layout," *VLSI Systems Design*, July 1987.

5. DeFalco, John A, "Predicting Crosstalk in Digital Systems," *Computer Design*, June 1973.

6. Stanford-Berkeley Associates, "High-Speed Interconnects" and "Chip and Package Interconnects," *The Electrical Performance & Design Guide Book*, 1993.

Authors' Biographies

Greg Seltzer is a product manager at Mentor Graphics Corp, where he has worked for seven years. He's responsible for board-level business based on high-speed applications. Seltzer was instrumental in developing of Mentor's Board Station 500 and Board Designer High Speed products. He attended State University of New York at Stony Brook, NY, where he obtained his BSEE. A member of the IEEE, Seltzer enjoys family activities, skiing, and tennis in his spare time.

Reza Ahy has been a consulting advisor at Stanford-Berkeley Associates for two years. Holder of a PhD in EE from Stanford University, Stanford, CA, Ahy is responsible for advising on technical directions in cross-product lines, multibusiness units, and R&D projects. Ahy's specialty is designing high-speed devices and systems. He is a member of the IEEE, ISHM, and IEPS. Ahy is recipient of the IEEE 1992 Microwave Award. His leisure-time activities include skiing, running, swimming, and business development.

Monica Razmi is vice president of marketing at Stanford-Berkeley Associates, where she has worked for two years. In charge of business development for high-speed products, she helped develop Stanford-Berkeley's High-Speed Interconnect and Chip & Package Interconnect design guidebooks. A member of ISHM, Razmi obtained a BSIE at the University of California at Berkeley. Her hobbies are music and dance.

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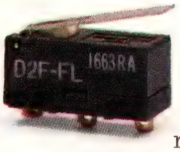

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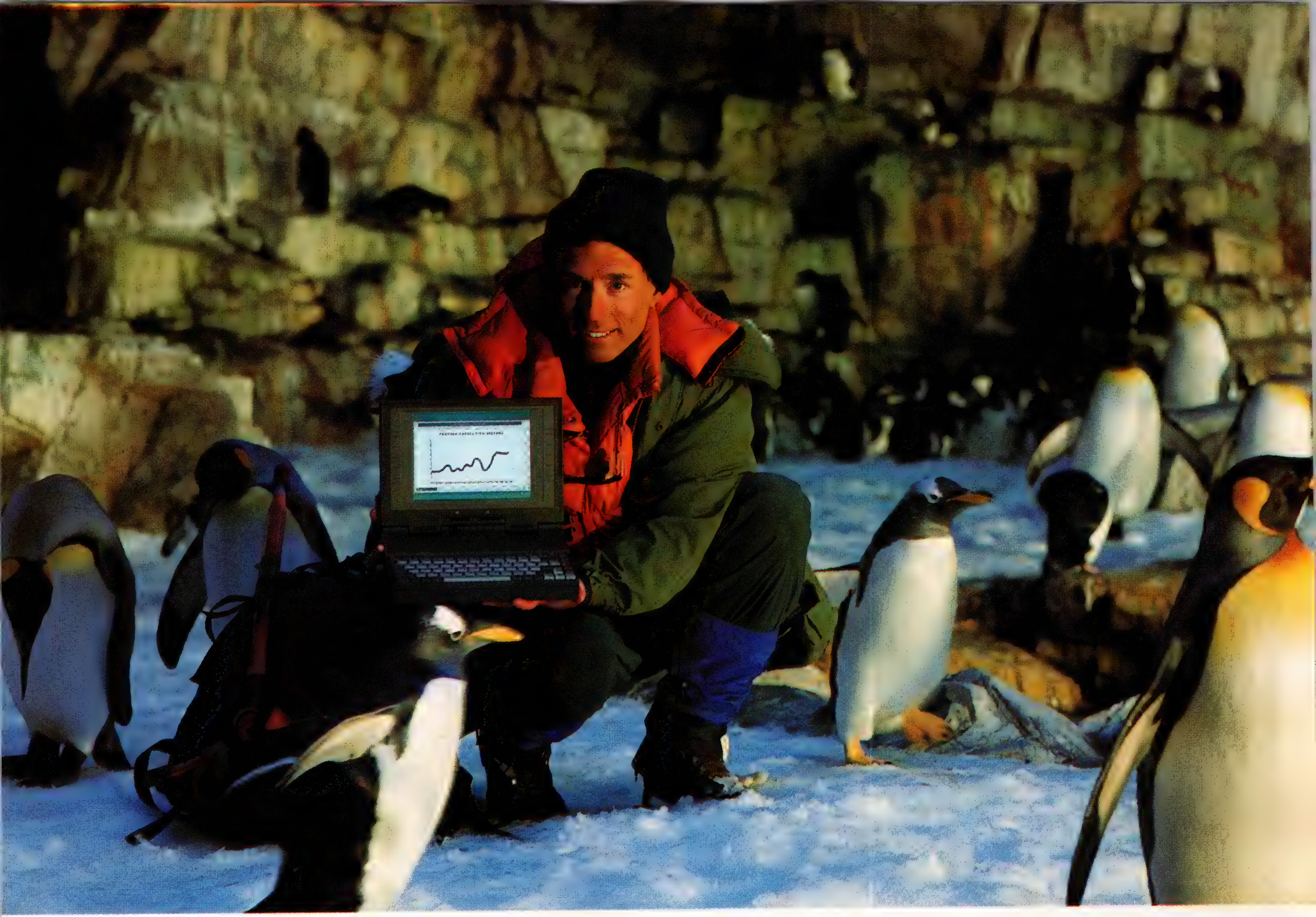

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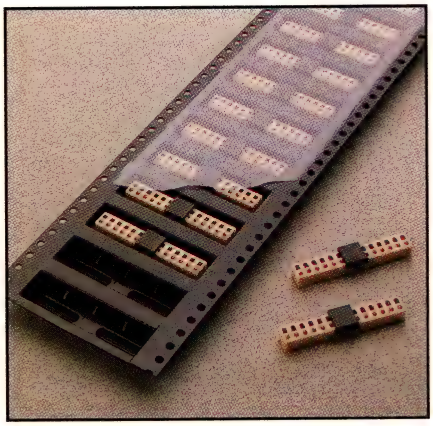

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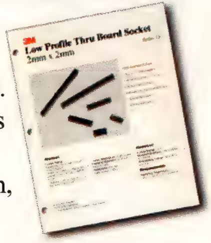

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CIRCLE NO. 26

10-bit, 40M-sample/sec ADC pairs high accuracy with low power

Built using a proprietary BiCMOS process and a pipeline architecture, the HI5702 from Harris Semiconductor achieves a minimum of 8.3 effective number of bits when digitizing a 10-MHz, 2.5V p-p input. The input stage of the ADC, which includes an S/H amplifier, can accept single-ended or differential signals. The maximum power dissipation is 600 mW.

Previous attempts to achieve 10-bit resolution and 40M-sample/sec rates used flash architectures that dissipated many watts and cost hundreds of dollars. Now, the 5702 joins a handful of ADCs (from Analog Devices (Norwood, MA), Crystal Semiconductor (Austin, TX), and Signal Processing Technologies (Colorado Springs, CO)) that consume lower power and have more reasonable price tags. The 5702's pipeline architecture, dynamic specifications, low power consumption, and single 5V power supply make it unique.

As is true with all ADCs, a converter's stated resolution does *not* equal its operating accuracy, particularly at frequencies approaching and close to the Nyquist rate of the converter. At higher sampling rates, a converter's S/N ratio and the related effective number of bits begin to fall off. Often, data sheets don't include enough information to find out the exact level of converter accuracy at the input frequency of interest. However, the 5072 comes with a full set of ac specifications at 1, 5, and 10 MHz.

This list includes the following guaranteed 10-MHz dynamic specifications: effective number of bits (8.3 min), S/N ratio (53 dB min), S/N ratio including distortion (51 dB min), THD (–57 dBc max), second-harmonic distortion (–63 dBc max), third-harmonic distortion (–58 dBc max), and spurious-free dynamic range (58 dBc min). Intermodulation distortion with f_1=1 MHz and f_2=1.02 MHz is typically −57 dBc. The ADC's full-power input bandwidth is 250 MHz, which is achieved via an open-loop S/H circuit.

No missing codes are guaranteed from 1M samples/sec to the maximum conversion rate of 40M samples/sec. Maximum integral and differential linearity errors are 2 and 1LSB, respectively.

Key to the ADC's performance is a process technology that allows for a simple implementation of a 10-stage pipeline. The ADC consists of nine 2-bit converters followed by a 1-bit converter. Each 2-bit stage assembles part of the output data, passes the result on to the next stage, and then begins working on the next input data. Each converter stage contributes 2 bits to the final output; 1 bit of each provides information for error correction. At the final assembly stage, a digital-error-correction circuit takes the 19 data bits from all stages, corrects for any errors indicated by the extra bits, and produces the final 10-bit output.

Because input data must ripple through the stages, the ADC has a finite latency time of seven clock cycles after it takes an analog sample. The ADC outputs each succeeding sample at the following clock pulse.

This pipeline architecture saves die area and power consumption. A flash architecture would require 1023 comparators to achieve the same 10-bit resolution, and a two-stage converter would take 94 comparators plus one amplifier. The 5702 uses only 19 comparators and 10 amplifiers.

Pipelined ADCs are not yet common because the architecture places certain requirements on amplifier performance and thus the fabrication process. For a 40-MHz conversion, the amplifiers in the pipeline should settle within a 1/2 LSB error band in a half clock period or 12.5 nsec. High open-loop gain is necessary to minimize the errors due to finite amplifier gain. The HBC-10 BiCMOS process allows easier development of amplifiers with the settling times and high gain necessary to achieve maximum accuracy using a straightforward single-stage pipeline.

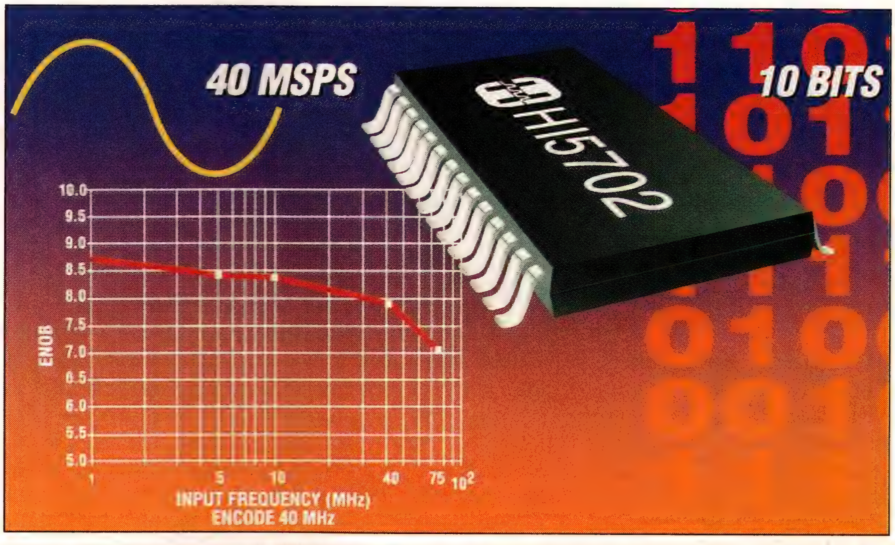
Other converter features make the ADC usable at conversion and input-data rates beyond 40 and 10 MHz, respectively. With 75-MHz inputs, the ADC's typical 7.1 effective numbers of bits make it applicable to direct digital IF at 70 MHz for satellite receivers. The ADC's wide bandwidth, spurious-free dynamic range, and effective number of bits allow undersampling of analog IF frequencies.

In 28-pin SOICS, two grades of the ADC are available: the 40M- sample/sec K grade ($45.35 (1000)) and the 36 M-sample/sec J grade ($38.65). Both are rated for the 0 to 70°C range.

—Anne Watson Swager

Harris Semiconductor, Melbourne, FL. (800) 442-7747, ext 7243.

Circle No. 312



Using a BiCMOS process, the HI5702 implements a straightforward pipeline architecture that provides 8.3 effective numbers of bits at 10 MHz.

INTEGRATED CIRCUITS

PLDs offer as many as 3200 usable gates. The EPM7160E and EPM7128E members of the MAX-7000E PLD family employ a 0.8-µm CMOS EPROM process. Both devices feature a 10-nsec pin-to-pin (t_{PD}) propagation delay. The MAX-7000E includes six output enables, two global clocks, and programmable output-slew-rate control. The 160-macrocell EPM7160E offers 3200 usable gates in 84-pin PLCCs or 160-pin PQFPs. The 128-macrocell EPM7128E offers 2500 usable gates in 84-pin PLCCs and 100- or 160-pin PQFPs. Both devices are drop-in replacements for other MAX7000 devices. In 84-pin PLCCs, the EPM7160E and EMP7128E cost $44.40 and $21.75, respectively. **Altera Corp**, San Jose, CA. (408) 894-7000.
Circle No. 317

Photodiode/amplifier ICs have precision outputs. The OPT202 and OPT209 integrate a 0.09×0.09-in. photodiode, a precision FET-input transimpedance amplifier, and a 1-MΩ feedback resistor. The ICs convert photodiode current to an output voltage proportional to light intensity. The 209's bandwidth is 16 kHz for general-purpose applications. The 202's bandwidth is 50 kHz for pulsed-light applications, such as bar-code scanners. Photodiode responsivity is 0.45 A/W at 650 nm. Other specifications include 2-mV dark errors, 400-µA quiescent current, 0.05% nonlinearity, and a ±2.25 to ±18V supply range. In 8-pin DIPs, the 202 costs $4.25; the 209, $5.25 (1000). **Burr-Brown Corp**, Tucson, AZ. (602) 746-1111.
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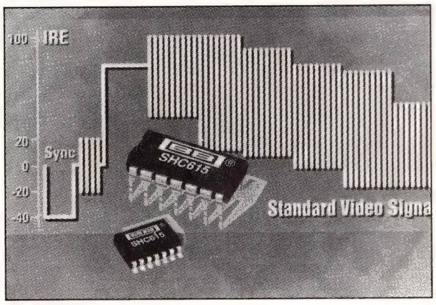

DC restorer suits many purposes. The SHC615 subsystem provides dc restoration, offset clamping, and low-frequency hum suppression of wideband amplifiers and buffers. You can also use the circuit as an S/H amplifier, a high-speed integrator, or a peak detector for nanosecond pulses. Key specifications include 280-MHz bandwidth, 2.2-nsec propagation delay, 1700-V/µsec slew rate, 4-nV/$\sqrt{10}$Hz, and 600-mW max power dissipation. The device comes in 14-pin DIPs and SOICs, and prices start at $7.95 (100). **Burr-Brown Corp**, Tucson, AZ. (800) 548-6132.
Circle No. 319

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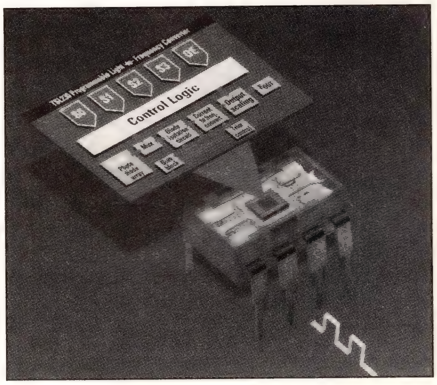
Chip set targets Pentium home-PC market. The 5V Apollo core-logic chip set suits use in 60/66-MHz Pentium VL-bus PCs. The chip set comprises a 208-pin VT82C535 system controller, two 100-pin VT82C531MV data buffers that isolate the CPU bus from the DRAM/VL/ISA buses, and a glueless interfaced 100-pin VT82C406MV-integrated X-bus peripheral controller. The peripheral controller includes a multiple-clock generator, a real-time clock, and a keyboard controller with PS2 mouse support. The chip set supports as much as 512 Mbytes of DRAM grouped into four pairs. DRAM data is placed in a secondary cache comprising synchronous or standard SRAMs. Unit price is $28. **VIA Technologies Inc**, Fremont, CA. (510) 683-3300.
Circle No. 320

8-bit, 40M-sample/sec ADC dissipates 110 mW. The HI1179 includes an S/H amplifier, a reference, and an on-chip sync clamp to eliminate several external components used for dc restoration. The on-chip reference sets the analog-input range for 0.6 to 2.6V. External references can range between 0 and 2.8V. Maximum integral and differential nonlinearity errors are ±1.3 and ±0.5 LSB, respectively. Differential phase and gain errors are 0.5° and 1%, respectively. In 32-pin PQFPs, the IC costs $10.16 (1000). **Harris Semiconductor**, Melbourne, FL. (800) 442-7747.
Circle No. 321

PC chip set handles dual 3.3V Pentium processors. The 3.3V Apollo chip set works with one or two Pentium processors with internal speeds of 100 MHz and above. The set provides circuitry for shared-memory coherency, interprocessor communication, and bus arbitration. The set comprises a system controller; two data buffers to isolate the CPU from the DRAM, VL, and ISA buses; a VL-to- PCI bridge; and an X-bus peripherals controller with keyboard and mouse interfaces, as well as a real-time clock. Integrated power-management circuits control system energy use, running the processor interfaces at 3.3V and the DRAM and the ISA buses at 66 MHz, 5V. The set costs $48. **VIA Technologies Inc**, Fremont, CA. (510) 683-3300. **Circle No. 322**



IC converts light to digital data. The TSL230 integrates photodiode, op-amp, and ADC functions on one chip. The IC operates from a 3 to 6V power supply and consumes 5 mW at 3V. A power-down mode reduces supply current to 10 µA. The device transforms the photodiode's current output to a pulse train whose frequency is proportional to the incident light intensity. Using an electronic-aperture technique, sensitivity is pin-programmable to 1-, 10-, or 100-times settings, which effectively give the device a 160-dB measurement range. The serial output interfaces directly with microcontrollers, DSP µPs, and digital logic. In an 8-pin clear DIP, the IC costs $2.76 (1000). **Texas Instruments**, Denver, CO. (800) 477-8924, ext 4500.
Circle No. 323

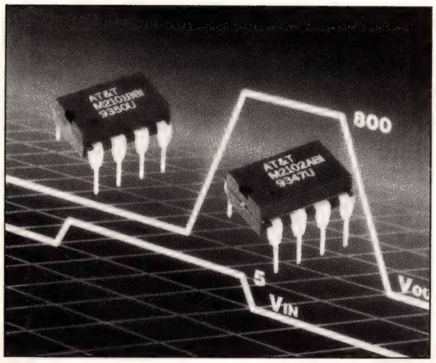
900-MHz RF front end simplifies wireless designs. The low-voltage SA601 integrates all of the front-end functions needed for a variety of wireless-receiver applications. These include a low-noise amplifier with a noise figure of 1.6 dB and power gain of 11.5 dB at 900 MHz, a down-convert mixer with 6 dB of conversion power gain and a noise figure of 10 dB at 900 MHz, a local oscillator buffer, and temperature- and supply-voltage-compensating bias circuitry. The performance of the amplifier and mixer are stable over temperature and the 2.7 to 5.5V supply voltage. Total current draw is 7.4 mA at 3V. In a 20-pin SSOP, the IC costs $1.74 (10,000). **Philips Semiconductor**, Sunnyvale, CA. (800) 447-1500, ext 3013.
Circle No. 324

EDN-NEW PRODUCTS

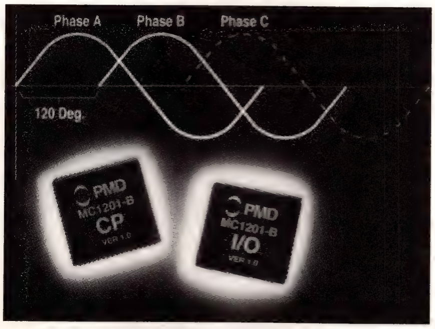
INTEGRATED CIRCUITS

10-MHz op amps operate down to 2.7V. The MAX473, 474, and 475 single, dual, and quad op amps operate from 2.7 to 5.25V. Each op amp requires 2 mA (3.3 mA max) of supply current while guaranteeing a 10-MHz bandwidth and a 15-V/μsec slew rate. The input range includes the negative supply rail, and the output swings to within 50 mV of each supply rail. The op amps can drive loads up to 600Ω. The devices come in 8-pin DIPs and SOICs, and prices start at $1.45. **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600. **Circle No. 325**

Clock generators drive PowerPC. The CGS700V, used in the Power Macintosh, provides nine clock signals for PowerPC 601-based designs. The device drives the CPU, cache memory, main memory, and bus-timing circuits. A related device, the CGS701V, provides the same clocks but uses an external feedback path. The devices offer period-to-period jitter guaranteed at <400 psec, with pin-to-pin skew <500 psec. They come in 28-pin PLCC packages and cost $10 (100). **National Semiconductor Corp**, Santa Clara, CA. (800) 272-9959. **Circle No. 326**



MOS gate drivers compete with discrete components. The ATT2101 low-side and ATT2102 high-side gate-driver chip set features a quick-response 2A sink-and-source output for driving MOS gates. The 2101 ($0.82 (10,000)) features a 3A totem-pole output to drive an N-channel power MOSFET or IGBT. This low-side driver contains protection circuitry that prevents simultaneous conduction of the low- and high-side gate drivers. Available with 600 or 800V level-shift capability, the 2101 can interface directly with the companion 2102. The 2102 ($0.60 (10,000)) features a 3A totem-pole output and undervoltage-lockout protection. It derives a floating supply by using a bootstrap technique. 8-pin DIPs and samples of surface-mount packages are available. **AT&T Microelectronics**, Allentown, PA. (800) 372-2447. **Circle No. 327**

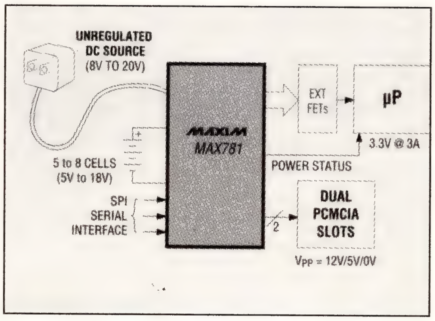


Chip set performs brushless-motor commutation. The MC1201-B motion-processor chip set performs sinusoidal commutation using the motor's encoder signal to determine the phasing. The ICs support several motor types, including 2- and 3-phase brushless and stepper motors. In stepper mode, the commutation provides the equivalent of 64 microsteps per full step. Standard features include four user-selectable profiling modes: S-curve, trapezoidal, velocity contouring, and electronic gearing. Supported feedback filters include PID and PI with velocity feedforward. Other features include two direction-limit switches per axis, a 16-bit DAC motor-output command support, 10-bit PWM output support, and a programmable loop rate to 200 μsec. In two 68-pin PLCCs, the chip set costs $85 (1000). **Performance Motion Devices**, Chelmsford, MA. (508) 256-1913. **Circle No. 328**

PCMCIA Ethernet IC offers full duplex. The NCR92C350 is an Ethernet transceiver IC with a PCMCIA interface. The device includes an AUI and a 10BaseT interface and is capable of operating in full-duplex mode under software or I/O pin control. It provides auto detection between AUI and twisted-pair interfaces and can be placed in a low-power sleep mode under software control. The 128-pin TQFP costs <$18 (1000). **NCR Microelectronic Products**, Fort Collins, CO. (800) 334-5454. **Circle No. 329**

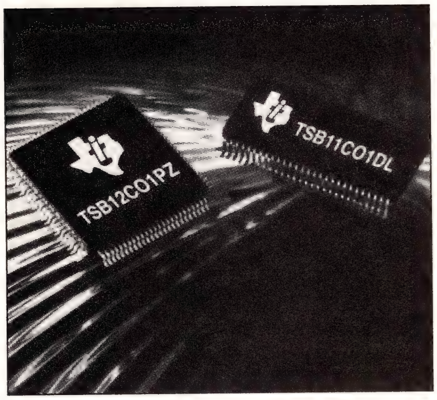
Pentium chip set includes VL bus. The Tiger chip set provides the core logic for a 60- or 66-MHz Pentium-based PC/AT. The device incorporates a 64-bit, level-2 writeback cache controller, 32-bit VESA-local (VL)-bus support, power-management control, and hooks to add a VL-to-PCI bridge. The two- chip set (ET5001/2) can handle up to 2 Mbytes of cache and 256 Mbytes of DRAM with two programmable non- cacheable regions. Prices range to <$30 (10,000). **ETEQ Microsystems Inc**, Milpitas, CA. (408) 432-8147. **Circle No. 330**

1-Mbit SRAMs have 8- to 12-nsec access times. A family of 1-Mbit SRAMs that have access times of 8, 9, 10, and 12 nsec is available. The devices have a 64k×18-bit or a 32k×36-bit organization. Other features include single-clock read/write operation, self-timed write operation, and compatibility with LVTTL I/O interfaces. The devices employ 0.5-μm technology and operate at 3.3V, which results in low power consumption. They come in 52-pin PLCC, 100-pin TQFP, and 7×17 ball-grid-array packages. $58 (1000). **IBM Microelectronics**, Hopewell Junction, NY. (914) 892-5389. **Circle No. 331**



Highly integrated power IC controls subnotebook computers. The MAX781 includes a 3.3V supply, dual PCMCIA analog controllers, a programmable battery charger, five high-side level translator outputs, and an SPI serial interface in a 36-pin SSOP package. The IC accepts inputs from NiCd or NiMH battery stacks of five to eight cells (5 to 18V). The 3.3V step-down converter uses an all-N-channel PWM synchronous-rectification switching scheme that provides 92% efficiency at full loads and quiescent currents of 1 mA. Fixed-frequency 300-kHz PWM switching minimizes output noise. $8.80 (1000). **Maxim Integrated Products**, Sunnyvale, CA. (408) 737-7600. **Circle No. 332**

Gate arrays facilitate mixed-voltage designs. The Universal PCI series of ASICs supports 5 and 3.3V and future voltages. The devices can interface with all three varieties of PCI signals defined by the PCI local-bus specification. The ASIC's PCI buffer can adjust its signaling level to the supply voltage of a system's PCI bus at either 3.3 or 5V. The gate arrays also support Gunning Transceiver Logic interfaces and other standard interfaces such as CMOS, LVCMOS, TTL, and LVTTL. The series features as many as 223,000 available gates and 14 base arrays. Power dissipation is 2.7 μW/MHz/gate and a 290-psec propagation delay for a 2-input NAND gate with a fan-out of 2. $6 to $60 (10,000). **NEC Electronics Inc**, Mountain View, CA. (800) 366-9782. **Circle No. 333**

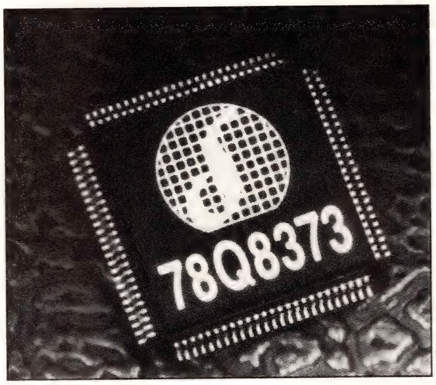


Chip set implements FireWire serial bus. A two-chip set implementing the FireWire serial bus provides serial data links at 100 Mbps. The TSB11-C01DL ($13) provides the physical-layer interface to the cable. The device offers three communications ports, allowing branch connections, as well as bus arbitration and initialization logic. The TSB12C01PZ ($32) provides the link layer, formatting data packets, generating and checking CRC, and connecting to the system host. The devices support the proposed IEEE P1394 standard for a high- performance serial bus. **Texas Instruments**, Denver, CO. (800) 477-8924, ext 4500. **Circle No. 334**

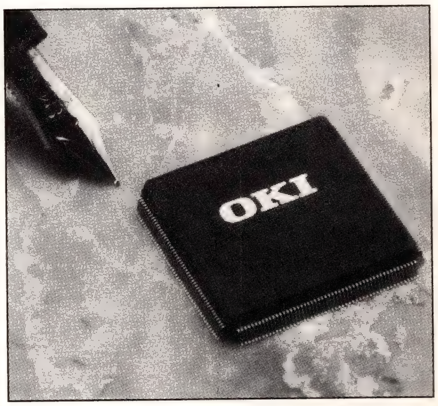
2-Mbit DRAMs have two CAS pins. The HM512200B 2-Mbit DRAM has a 1M×2-bit organization. The device is optimized for use as parity bits in memory cards and modules. Because the DRAM has two independent CAS control signals, it replaces two 1-Mbit DRAMs. The DRAM offers a fast page-access mode, which provides an accesss time of 60, 70, or 80 nsec. The standard version of the 5V device uses 1024-cycle/16-msec refresh, with RAS only, CAS before RAS, and hidden refresh modes. The device draws 70 mA operating and 2 mA in standby mode. $12.75 (1000). **Hitachi America Ltd**, Brisbane, CA. (800) 285-1601. **Circle No. 335**

5V ASICs feature low power. The TC170 series is comprised of the TC170G gate array and TC170C standard cell. The devices employ 0.7-μm CMOS technology and feature a power dissipation of 4.4 μW/MHz/gate and gate complexities ranging from 22,000 to 194,000 gates for the TC170G and 5000 to 219,000 for the TC170C. The devices also feature 270-psec gate delays (loaded) and double-layer metallization. The TC170G/C costs $15 for 45,000 gates (OEM). **Toshiba America Electronic Components Inc**, Irvine, CA. (714) 455-2000. **Circle No. 336**

FPGAs have 4000 gates. The CY7C385A and CY7C386A are 4000-gate versions of the company's pASIC family of FPGAs. The FPGAs combine high-speed, high-density Vialink programming elements with the company's 0.65-μm process. The programming element is one-seventh the size of SRAM-based programming elements. The smaller programming elements give the FPGA one-twentieth the capacitance and resistance of SRAM-based devices, improving speed and reducing power consumption. The CY7C385A has as many as 88 I/O pins and comes in an 84-pin PLCC and a 100-pin TQFP. The CY7C386A has 128 I/O pins and comes in a 144-pin TQFP. The CY7C385 in a PLCC costs $87.70 (100). **Cypress Semiconductor Corp**, San Jose, CA. (408) 943-2600. **Circle No. 337**



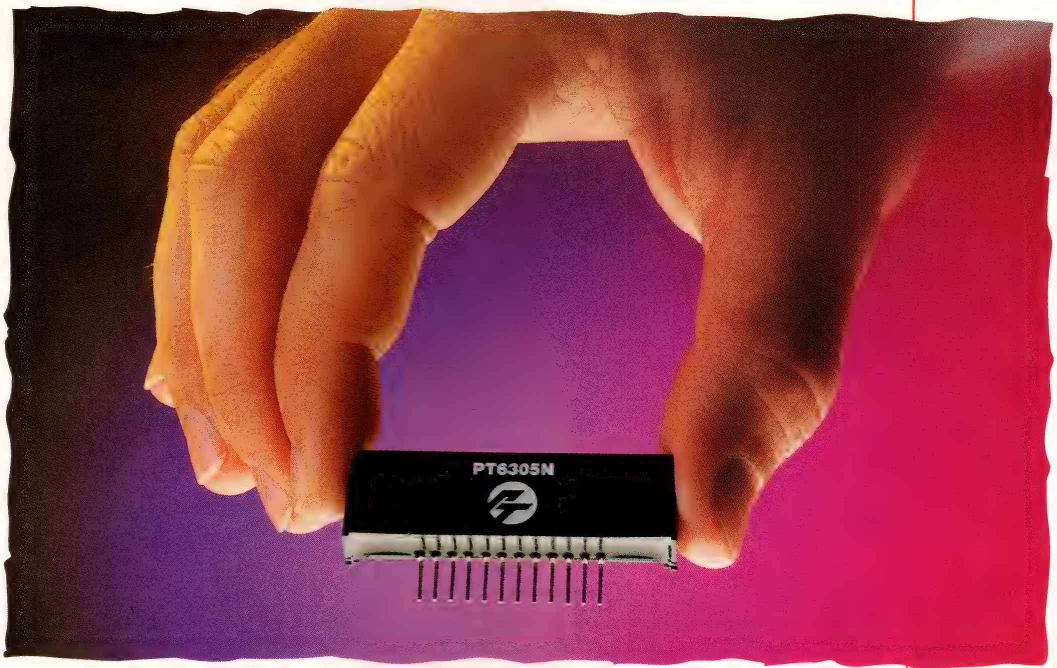
PCMCIA Ethernet IC runs dual voltage. Needing only memory and a few passive components, the 78Q8373 provides a 10BaseT Ethernet PCMCIA card in essentially a single chip. The device integrates a media-access controller, Manchester encoder/decoder, PCMCIA bus interface, 10BaseT transceiver, and attachment unit interface into a 100-lead TQFP. The device runs at 3.3 or 5V and offers three operating modes to software control of power use. The device sells for around $19 (100). **Silicon Systems**, Tustin, CA. (800) 624-8999, ext 150. **Circle No. 338**



Gate-array family optimized for mixed voltages. The MSM13R series employs 0.5-μm technology to develop a sea-of-gates ASIC family. The family has a 3V core and a 3 or 5V I/O interface. The family has a maximum usable gate count that exceeds 500,000 gates, and a 2-input NAND internal gate that has 110-psec propagation delay. The array's 624 configurable I/Os employ a narrow bonding-pad pitch of 100 μm. The arrays employ three layers of metallization, and the current family has 10 basic arrays. **Oki Semiconductor**, Sunnyvale, CA. (408) 720-1900. **Circle No. 339**

Neuron chip reaches second generation. The TMPN3150BF and TMPN3120BM are second-generation versions of the Neuron chip used for intelligent distributed control using Echelon Corp's Lonworks control technology. The devices communicate on a peer-to-peer network over serial links through a variety of media. Each device has three 8-bit CPUs, two for handling communications and one for the control task. The devices also contain EEPROM for configuration data and RAM. The 3150 has 2 kbytes of RAM; the 3120 has 1 kbyte of RAM and 10 kbytes of ROM. Improvements in the second generation include external memory access and reduction of power consumption by ½ during operation and from 500 to 15 μA in sleep mode. Price is around $5 (10,000). **Toshiba America Electronic Components Inc**, Irvine, CA. (800) 879-4963. **Circle No. 340**

SINGLE-DEVICE 5V TO 3.3V POWER



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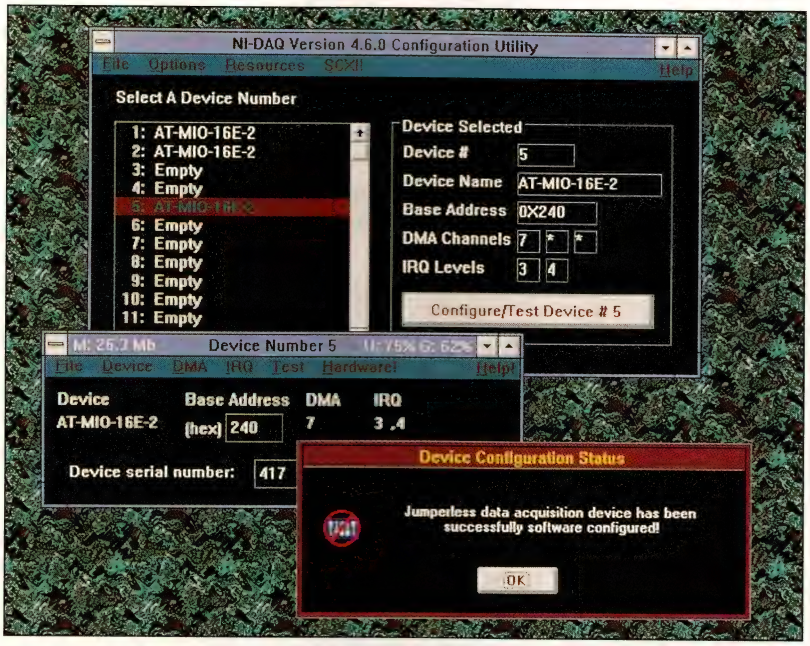
CIRCLE NO. 86

$1595 data-acquisition board features 3-MHz bandwidth, equivalent-time sampling, Plug-and-Play configuration

ISA bus data-acquisition boards that acquire signals whose bandwidth ranges into megahertz regions have been available for several years. A few boards even use equivalent-time sampling to accurately digitize repetitive signals containing high-frequency components that would cause aliasing if sampled at the ADC's normal maximum rate. However, most such boards cost over $2000 or lack features expected in "mainstream" products. Now, though, National Instruments' AT-MIO-16E-2, a full-featured unit priced at the market's $1595 sweet spot, uses equivalent-time sampling to acquire 3-MHz signals—even at gains of 100. In real time, the board's 12-bit ADC takes 500k samples/sec on 16 channels (eight differential).



Select A Device Number

1: AT-MIO-16E-2
2: AT-MIO-16E-2
3: Empty
4: Empty
5: AT-MIO-16E-2
6: Empty
7: Empty
8: Empty
9: Empty
10: Empty
11: Empty

Device Selected
Device # 5
Device Name AT-MIO-16E-2
Base Address 0X240
DMA Channels 7 * *
IRQ Levels 3 4

Device Number 5

Device	Base Address	DMA	IRQ
AT-MIO-16E-2	(hex) 240	7	3 ,4

Device serial number: 417

Device Configuration Status

Jumperless data acquisition device has been successfully software configured!

Gone are the days of popping the top of your PC and reconfiguring an ISA bus data-acquisition board's jumpers or switches to set addresses, interrupt levels, and other operating parameters. With the Plug-and-Play-configurable AT-MIO-16E-2 and -16XE-50 from National Instruments, you simply run the software shown here. When MS-Windows 4.0 (Chicago) is available, it will take over the configuration function. Like some other data-acquisition boards, these E-series units also eliminate manual gain and offset trims.

High-frequency acquisition tops a list of features that seem destined to raise users' expectations for moderately priced data-acquisition boards. Although you've been able for several years to buy boards that perform all of their offset and gain trims via software, the AT-MIO-16E-2 not only is free of analog trims, but also does away with address jumpers and switches. It conforms to the ISA bus Plug-and-Play standard to be implemented in MS-Windows V4.0 code-named "Chicago." Until Chicago becomes available, you can configure the board by using a utility program shipped with it. A $995 330k-sample/sec board, the DT31-EZ, which Data Translation announced in May, is fully software configurable except for the base address.

The other area where the AT-MIO-16E-2 moves ahead of its competition is in the flexibility of its counter/timers. A system-timing-controller ASIC, the DAQ-STC clocked at 20 MHz, handles timing and ADC triggering. The IC contains 10 counter/timers: Four are for the analog inputs; four are for the analog outputs. Users can access a 4-bit programmable frequency divider and two 24-bit general-purpose up-down counter/timers that have double-buffered inputs. The ASIC is at the heart of the sequential equivalent-time sampling, which allows an effective capture rate of 20M samples/sec for repetitive signals.

The ASIC also implements functions that aren't available with the general-purpose counter/timers on most data-acquisition boards. For example, when an alarm condition arises, the ASIC can immediately increase the ADC's sample rate—without the usual unpredictable delay for reprogramming the counter/timers.

On the long list of additional features are: two 12-bit analog outputs, eight TTL I/O lines—each of which can sink 24-mA, programmable analog-input gains of 1 to 100 in seven 1-2-5 steps, a 512-point channel-gain-list memory that lets you program each channel's sampling rate and gain, dual-channel DMA, separate 2k-word FIFO buffers for analog inputs and outputs, the ability to transfer data under interrupt or programmed I/O control, and use of the vendor's RTSI (real-time system integration) bus to synchronize multiple boards. You extend the RTSI bus by running a ribbon cable over the tops of your ISA bus boards.

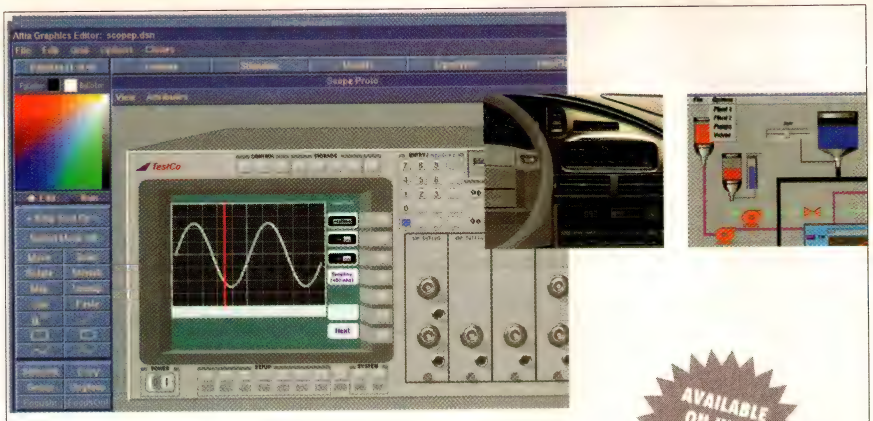
As you would expect from a National Instruments board, the vendor provides software support via NI-DAQ drivers for DOS and Windows, LabWindows for DOS, and LabView and LabWindows/CVI for Windows.

A lower cost board, the $995 AT-MIO 16XE-50, also features Plug-and-Play configurability. The board, whose maximum A/D conversion speed is 20k samples/sec, shares most of the features of the AT-MIO-16E-2—even its ability to accept 16 pseudo-differential inputs. (Such inputs are referred to a common ground whose potential can differ from that of the board's ground.) The $995 board lacks the proprietary NI-PGA programmable-gain amplifier that maintains a 3-MHz bandwidth at all gains. Also, the board's FIFO buffers store only 512 words each.

—Dan Strassberg

National Instruments Corp, Austin, TX. Phone (512) 794-0100. **Circle No. 310**

Data Translation Inc, Marlboro, MA. (508) 481-3700. **Circle No. 311**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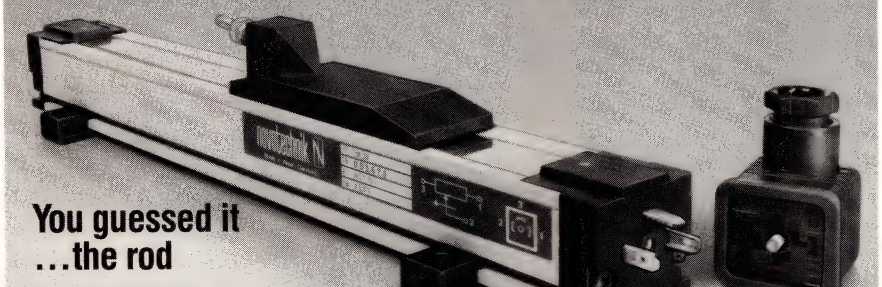
CIRCLE NO. 46

What's missing from this transducer?



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CIRCLE NO. 47

EDN-NEW PRODUCTS

TEST & MEASUREMENT

Macintosh data-acquisition software spools 100M-sample records to disk. SuperScope II V1.2 analyzes and graphs digitized waveforms. It can also perform calculations on the waveform data, store annotated waveforms, and create waveform databases. The package allows exporting of data to spreadsheets, word processors, database managers, graphing packages, and math packages. $750; $1490 with analysis capabilities. **GW Instruments,** Somerville, MA. (617) 625-4096. **Circle No. 376**

Generator produces predefined and arbitrary waveforms at 40V p-p. The PM 5138A has an output bandwidth of 10^{-4} Hz to 10 MHz. It allows you to vary the symmetry of output waveforms and permits amplitude and frequency modulation, phase-shift keying, bursting, gating, and linear or logarithmic sweeps. A back-lit LCD provides a menu-driven user interface; a rotary control permits simple entry of numeric values. You can order the generator with IEEE-488 or RS-232C interfaces. A nonvolatile memory stores nine setups, which can be invoked from the front panel or remotely. On power-up, the last settings are automatically restored. $3700. **Fluke Corp,** Everett, WA. (800) 443-5853. **Circle No. 377**

Active extender for VESA local bus safeguards your PC. The VEE lets you insert and remove adapter cards from a PC with power on. The extender includes adjustable overcurrent-detection circuits, which remove power from boards under test that draw too much current. You can use a hardware switch or software commands to control both power and bus signals to the board under test. **AZ-Com,** $749. Orinda, CA. (510) 254-5400. **Circle No. 378**

Pod lets ISA bus logic analyzer generate arbitrary waveforms and digital patterns. You can obtain the $475 Digital/Analog Pod as an ISA bus board or as an instrument-level product that communicates with the host PC via a parallel port. The pod, which works with the vendor's ETLAplus PC-based logic analyzer, provides two 8-bit-resolution analog outputs and 16 digital outputs (expandable to 48). The pattern-memory depth is 32k frames, and the maximum clock rate is 25 MHz. **Emulation Technology Inc,** Santa Clara, CA. (408) 982-0660. **Circle No. 379**

COMPONENTS

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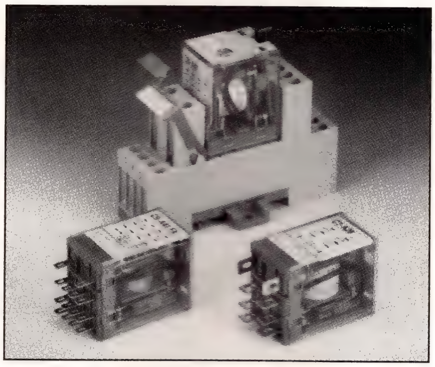
Diodes withstand 4 to 20 kV. The Beta Series of high-voltage diodes operates with voltage ratings from 4 to 20 kV and handle 5 mA. The diodes have a 100-nsec reverse-recovery time and moderate peak forward-voltage ratings ranging from 20 to 60V. The plastic-bodied, axial lead diodes measure 0.118×0.315 to 0.472 in. $0.40 to $0.60 (50,000). **Applications Engineering Inc**, Danbury, CT. (203) 790-1861. **Circle No. 380**

Thin-film resistor networks terminate advanced µP's buses. The IPEC R-Net thin-film resistor networks terminate buses for pc boards bearing µPs such as the 486, the Pentium, and the PowerPC, as well as common RISC µPs. The units replace discrete resistors or resistor networks using other technologies and offer improved high-frequency performance. $0.34 to $0.82. Prototype samples are available now; delivery of production units is six to eight weeks ARO. **California Micro Devices Corp**, Miltpitas, CA. (408) 263-3214. **Circle No. 381**

Active linear filters operate at high frequencies. The D01 series of active filters has corner frequencies from 50 kHz to 1 MHz. The linear devices come in a 32-pin DIP. These filters' total harmonic distortion is <–80 dB at 1 kHz. Out-of-band attenuation is at least 80 dB. The filters offer 4-, 6-, and 8-pole Butterworth or Bessel transfer functions. The 4-pole filter costs $74; the 8-pole device, $116 (1000); delivery is three to four weeks ARO. **Frequency Devices**, Haverhill, MA. (508) 374-0761. **Circle No. 382**

Extruded-aluminum electronics enclosures come in nine off-the-shelf sizes. Additions to the Tech-Box line of extruded-aluminum electronics enclosures come in nine sizes ranging from 2.125 to 6.762 in. wide and from 0.625 to 2.720 in. high. The enclosures come with 2- to 9-card slots and accept cards from 2.38 to 6.5 in. wide. You can receive a free sample by sending your request on company letterhead. Accessories include associated panels, hardware, and rubber feet. Optional features include custom finishes and RFI/EMI shielding. Single-slot enclosure, $4.78 in large quantities; 2-slot, $5.38. **Extrusion Technology**, Randolph, MA. (617) 963-7200. **Circle No. 383**

Ovenized oscillator comes in industry-standard package. The model 252-1130 5-MHz ovenized oscillator offers a thermal stability of 1×10^{-9} ($\pm5\times10^{-10}$) over a temperature range of –30 to +70°C. Aging is better than 5×10^{-11}/day and 1×10^{-8}/year. The device's phase noise is –110 dBc/Hz at a 1-Hz offset, –145 dBc/Hz at 100 Hz, and –160 dBc/Hz at 10 kHz. HCMOS or +7-dBm sine-wave outputs are available. The oscillator's case measures 2.36×2.64×1.06 in. $640. **MTI-Milliren Technologies Inc**, Newburyport, MA. (508) 465-6064. **Circle No. 384**



Ultrathin "ice-cube" relay has pull-to-test button. The Ice Cube Plus line of relays sports both mechanical and optional optical status indicators (LEDs or neon bulbs, depending on coil voltage). When you pull a tab in the top of the relay, the relay jams in its on-state. The relay and socket both accept snap-in labels. The narrow relays mount in a 22.5-mm-wide socket. You can mount the sockets on a DIN rail or use the sockets' single-screw mounting tab. A built-in clip holds the relay securely in the socket. Dual-pin numbering on the socket conforms with all international standards. The device comes in 2- and 4-pole versions. The relays withstand 100 million operations at full load. Singles, $8 to $15. **Turck Inc**, Minneapolis, MN. (612) 553-7300. **Circle No. 385**

Analog adapter board provides easy access to analog-I/O signals from PC-based data-acquisition board. The model UEI-BNC/01 analog adapter board features BNC connectors that route analog-I/O signals. The devices accommodate single-ended

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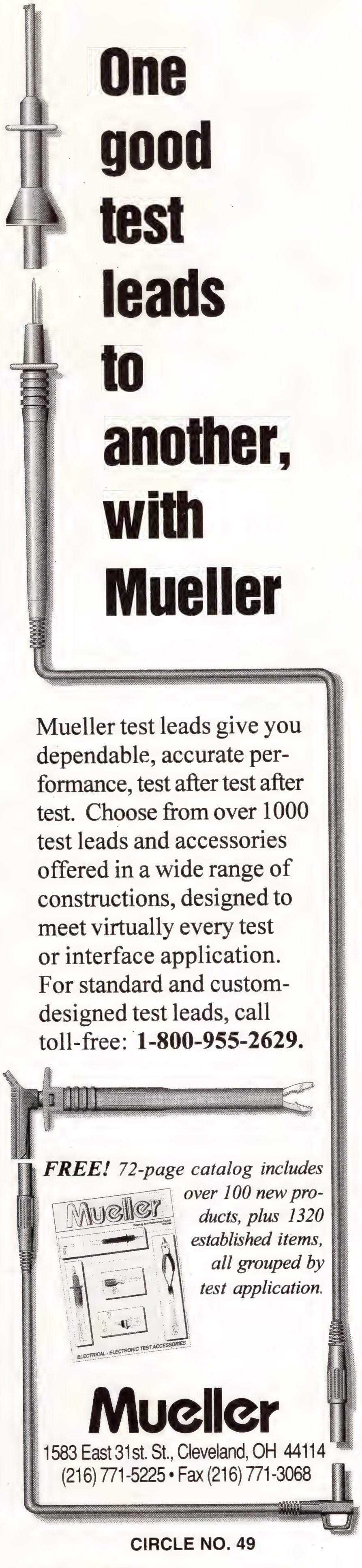

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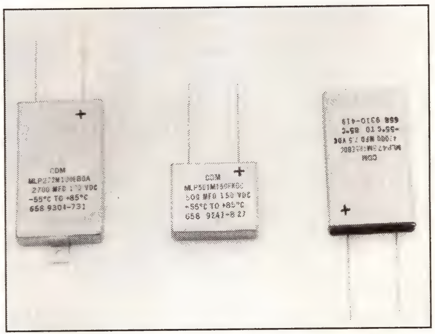
and differential analog inputs and offer component locations for building RC filters, voltage dividers, and trigger circuits. $395; delivery is from stock. **United Electronic Industries**, Watertown, MA. (617) 924-1155. **Circle No. 386**



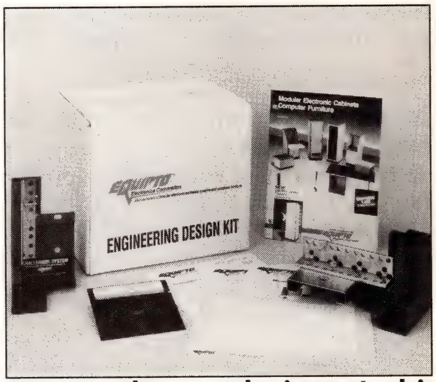
Flatpack aluminum capacitors conserve pc-board space. The MLP family of flatpack electrolytic capacitors includes half-size units measuring 0.50×1.75×1.5 in. The units are available in capacitances ranging from 560 µF to 47 mF. The units come with either two mounting tabs or an extra pair of leads. Their life rating is 2000 hours at 85°C. $25 (1000); delivery, six to 12 weeks ARO. **Cornell Dubilier**, Pickens, SC. (803) 878-7257.
Circle No. 387

N and SMA coaxial receptacles press-fit into system's housing. Unlike conventional N and SMA connectors, which have flanges and which must be screw mounted, a line of press-fit coaxial receptacles occupies minimal area (no larger than the cross-section of the threaded portion of the connector) and mounts in one step. The connectors come with tab, slotted, or solder-pot contact ends. N connectors, $2.45 (1000); SMA connectors, $2.21 (1000). **The Delta Electronics Manufacturing Corp**, Beverly, MA. (508) 927-1060.
Circle No. 388

Horizontal-mount toroidal inductors have through-hole leads. A series of through-hole inductors is available in 121 values ranging from 0.10 µH to 10 mH. The inductors' cores are powdered iron. $4 (100). **Engineered Components Inc**, San Luis Obispo, CA. (805) 544-3800.
Circle No. 389

Toroidal-winding spacers assure voltage isolation. The Common-Mode Torroidal choke spacers provide physical separation and electrical insulation of windings on torroidal common-mode chokes to assure voltage isolation between the windings. To assemble, you simply push a spacer into the hole in the torroid. You can insert a second spacer from the opposite side of the torroid. The spacers are available in 22 sizes. $0.10 to $0.20. **Robison Electronics Inc**, San Luis Obispo, CA. (805) 544-8000. **Circle No. 390**

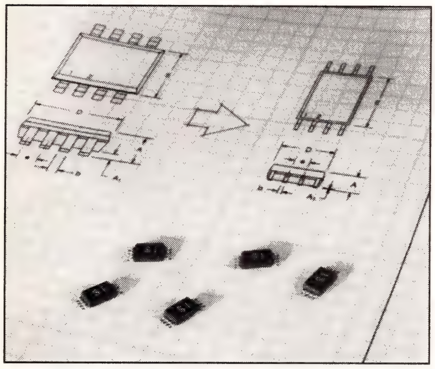
Gate-drive transformers for switching supplies offer low interwinding capacitance and leakage inductance. The low interwinding capacitance and leakage inductance of the GDT-series of FET gate-drive transformers allow rise times appropriate for switching frequencies from 25 to 100 kHz. The devices provide 4200V-rms isolation and have two fully floating outputs. Unlike optical isolators, these magnetic devices' characteristics are predictable and stable. 25 kHz, $2.70; 50 kHz, $2.03; 100 kHz, $1.82 (1000); delivery is from stock. **GFS Magnetics**, Dover, NH. (603) 742-4375.
Circle No. 391



Free enclosure designer's kit available. Free to qualified engineers, a design kit for enclosures includes an IBM PC-specification program, samples of the company's frame corners, and a catalog that includes an EMI/RFI guide. **Equipto Electronics Corp**, Aurora, IL. (708) 897-4691.
Circle No. 392

Surface-mount, general-purpose, small-signal transistors come in ceramic packages. The NNTX-2N2222AUA and JANTX- 2N2222AUB NPN transistors come in a 4-pin hermetic chip carrier and a 3-pin leaded chip carrier (LCC), respectively. The LCC matches the SOT-23 footprint. The devices have the familiar 2N2222 specs except for a –65 to +200°C operating junction temperature, T_J. The devices cost $12.27 and $10.49 (1000), respectively. **Optek Technology Inc**, Carrollton, TX. (214) 323-2200.

Circle No. 393



Thin power transistors slip into PCMCIA cards. The Lite Foot family of n- and p-channel power MOSFETs comes in the 8-pin TSSOP (thin super-small-outline package). The devices can dissipate 1.5W without external heat sinks. The package measures 1.1 mm high and occupies 19 mm^2 of pc-board area. Breakdown voltages range from 12 to 30V. $0.88 to $1.32 (100,000); delivery 8 to 10 weeks ARO. **Siliconix**, Santa Clara, CA. (408) 988-8000.

Circle No. 394

Solid-state switch integrates ring detector and hookswitch. The TS series combines a hookswitch and ring detector in an 8-pin DIP. The switch handles input voltages of 400V pk ac or dc and loop currents up to 170 mA. The switch's on-resistance is 22Ω min, and switching speed is 3 msec max. The ring detector is sensitive to 2-mA loop currents. 3750V-rms input-output isolation is optional for compliance with European regulations. $2.78 (10,000); delivery stock to six weeks. **CP Clare Corp**, Wakefield, MA. (617) 246-4000.

Circle No. 395

Surface-mount "blocks" kill ripple and noise. A line of surface-mount, core-axial inductors in block form provides inductances ranging from 10 µH at 4A to 1 mH at 400 mA and measure 0.25 in. high. The devices replace more expensive and harder to install toroids. The ferrite blocks exhibit wide bandwidth, low dc resistance and ac losses, and flat frequency and current responses. The devices come in standard EIA 10% values. $2 (1000). **GFS Magnetics Inc**, Dover, NH. (603) 742-4375.

Circle No. 396

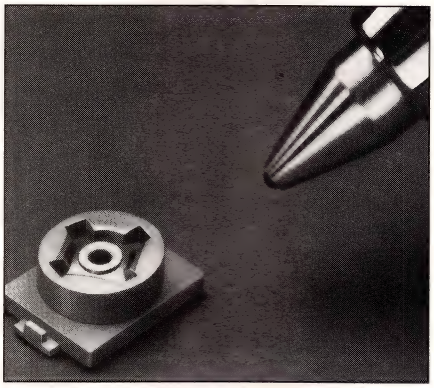
Capacitors suit microwave and RF applications. A line of capacitors includes multilayer ceramic and porcelain capacitors in chip and leaded styles, as well as variable or trimming capacitors. Some models operate at 300 GHz. The porcelain capacitors' Q factors are 10,000 min at 1 MHz. The variable capacitors Q factors range from 1200 to 10,000 at 100 MHz. Microwave trimmer capacitors having a sapphire dielectric exhibit Q factors ranging from 1500 to 5000 min at 250 MHz. $81.45 to $434.59. **North American Capacitor Co**, Indianapolis, IN. (317) 273-0090.

Circle No. 397

Flat-cable and flexible-circuit connectors feature numerous enhancements. The 71226 series of 1-mm, zero-insertion-force connectors for flat cable and flexible circuit boards features stronger latches, improved contact retention and location, and improved printed-circuit tail-tip geometry. The connectors optionally have cable-retention barbs and polarizing pegs. Optional kinked pegs lock the connector to the pc board before soldering. The connectors are available in even pin numbers from 4 to 30. A 22-pin version with optional barbs and pegs is $0.888 (25,000). **Molex Inc**, Lisle, IL. (708) 969-4550.

Circle No. 398

Multilayer trimming capacitors reduce surface-mount space requirements. A pair of surface-mount trimming capacitors measures 0.15×0.13×0.06 in. The model GKM-10066 ranges from 1.5 to 10 pF, and the model GKM20066 ranges from 5 to 20 pF. The capacitors' voltage rating is 50V dc, and insulation resistance is 10^4 MΩ min. $0.83 (1000); delivery stock to 12 weeks ARO. **Sprague-Goodman Electronics Inc**, Garden City Park, NY. (516) 746-1385.



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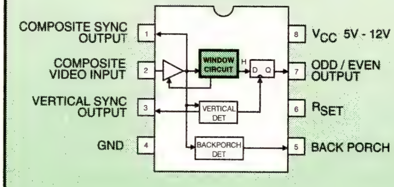

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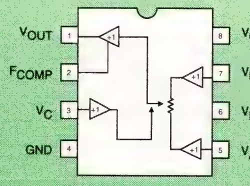

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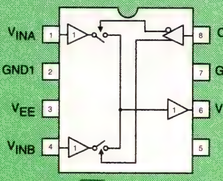

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Graphics modules handle X-Windows. The IP-SVGA and IP-UVGA graphics modules are Industry Pack-compatible graphics modules with resolution to 1024×768 pixels with 256 colors. A second family, the IP-LCD and IP-SLCD, offer both CRT and LCD-panel output signals. All have keyboard and PS/2 mouse interfaces. Software drivers supporting the boards include X-Windows, G-Windows, and MGR running under the OS-9 operating system, as well as low-level drivers for embedded applications. **Snijder Micro Systems**, Deurne, Netherlands. (31) 4930- 10725. **Circle No. 341**

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32-channel A/D board offers 100-kHz sampling. The Model 4275 VME-bus and the Model 4375 Multibus II modules provide a bank of 16-bit sigma-delta A/D converters for MIX baseboards. The modules include 32 converters, each sampling at rates to 100 kHz, along with signal conditioning. The signal conditioning provides buffering with a ±5V input range and attachment to a front-panel flat-ribbon connector. The modules also offer a 16k-sample FIFO buffer. Price is $5745. **Pentek Inc**, Norwood, NJ. (201) 767-7100. **Circle No. 342**

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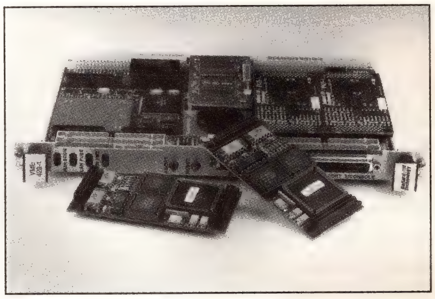
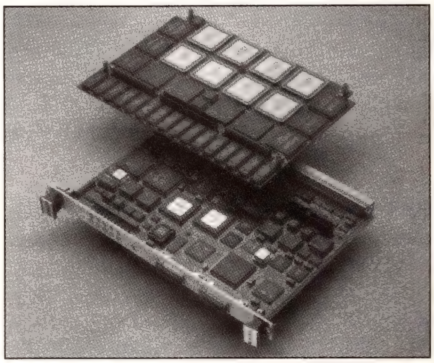


VME board provides ARINC interface. Handling as many as 24 channels, the VME429-1 brings the ARINC 429 avionics test bus to VME. The board offers software to handle message processing and is based on an MC68LC040 processor with 1 Mbyte of DRAM. Options include more DRAM, SCSI and Ethernet ports, and a floating-point processor. The device accepts Industry Pack modules for functional expansion. A 6-channel board costs $3995; a 24-channel board with SCSI, Ethernet, and advanced software costs $9995. **Ballard Technology Inc**, Seattle, WA. (800) 829-1553. **Circle No. 343**

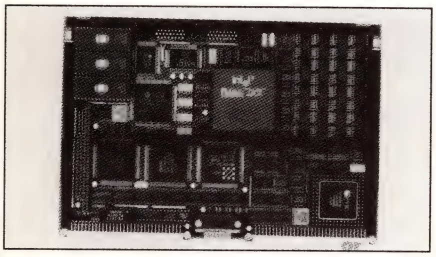


QuickRing comes to VME. The SuperCard-4SLX is a multiprocessor VME board offering National Semiconductor's QuickRing interface. QuickRing delivers bandwidth to 1.2 Gbytes/sec. The board also provides eight i860 processors arranged as four processing elements. It is software-

EDN-NEW PRODUCTS

BOARDS & BUSES

compatible with other SuperCard boards and costs $29,000. **CSPI**, Billerica, MA. (617) 272-6020. **Circle No. 344**

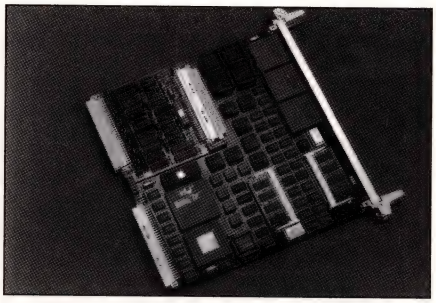


PC-compatible module survives harsh living. High shock and vibration immunity as well as a -40 to +85°C operating range characterize the RUGG-PC module. It is based on a 486 or a Pentium processor with 64 Mbytes of onboard RAM. The 6U VME module includes VGA, Ethernet, SCSI, and all standard PC I/O functions as well as a PC 104 bus interface for expansion. Rack-mountable enclosures incorporating floppy- and hard-disk drives are available. Prices start at $2614. **or Industrial Computers**, Mission Viejo, CA. (714) 855-3235. **Circle No. 345**

Board converts DSP to image processing. Using the IPI-40 interface board, any VME DSP board based on the TMS320C40 processor becomes an image processor. The 6U IPI-40 provides frame capture, 8×8 2D convolution, and RGB pseudo-color display drivers. The board can handle as many as four monochrome NTSC or PAL cameras with variable sample rates and frame size. It links to the DSP through the processor's Comport or to other digital video sources through a data bus. Prices are $5050 with a convolver and $3850 without a convolver. **Traquair Data Systems Inc**, Ithaca, NY. (607) 272-4417. **Circle No. 346**

Test bed accesses Futurebus+. The TB68EC020-20 accepts 6U VME boards and translates the VMEbus signals into Futurebus+ signals. It includes the board, monitor software, and an interface cable for connecting to a PC's serial port. The board is a minimal chip-set design based on the 68LC040 processor and occupies the space of a 12SU Futurebus board when mated with a 6U VME card. It also works with VME crate-to-crate adapters. The board costs $1995. **Technobox Inc**, Mount Laurel, NJ. (609) 778-5512. **Circle No. 347**

SCSI-2 adapter fits PC/104 form. Compatible with the Adaptec AHA1520 SCSI-2 interface, the SCSI-104 fits into the PC/104 envelope. The board allows a 10-Mbyte/sec burst-transfer rate and provides 5-Mbyte/sec synchronous and 2.5-Mbyte/sec asynchronous sustained transfers. In addition to handling seven SCSI devices, the board offers two serial ports and a PC/AT floppy-disk controller. It includes onboard BIOS, an Adaptec SCSI peripheral interface (ASPI) driver, and installation utility software. The price is $225. **Adastra Systems Corp**, Hayward, CA. (510) 732-6900. **Circle No. 348**



Multibus communications board offers eight serial links. The HC 486/Lxx uses the Siemens SAB82525 serial communications processor to offer eight channels of full-duplex communications with DMA. The board handles HDLC communication protocols with most layer-2 functions handled independently of the onboard 486 processor. The processor comes in 33-, 66-, and 100-MHz speeds. The serial I/O interfaces come on a removable module, allowing you to customize the connection. **Concurrent Technologies Inc**, Champaign, IL. (217) 356- 7004. **Circle No. 349**

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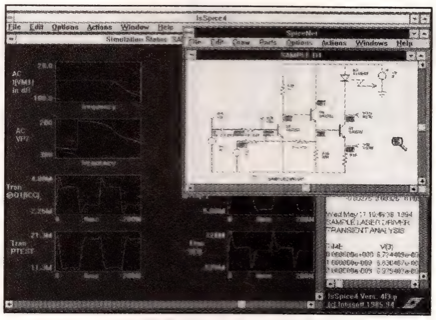
Verilog simulator offers parallel-processing speed. The Verilog- compiled simulator/multithreaded reduces simulation time for large ASIC models by as much as a factor of five. The simulator accepts standard Verilog HDL code and takes advantage of the concurrency inherent in most large designs. You indicate in a separate file the modules within a model that are relatively independent, and the simulator executes these portions in parallel. The simulator runs on the shared-memory multiprocessing workstations from Sun. A two-processor license fee is $55,000, and you can add processor licenses for $5000 each. **Chronologic Simulation**, Los Altos, CA. (415) 965-3312. **Circle No. 313**

Low-cost analog and mixed-signal circuit simulator runs under Windows. ICAP/4Lite eliminates some of the features available on ICAP/4Windows, but it is not limited in the circuit size it will accept. The 32-bit Spice simulator includes an integrated schematic-entry program, provides real-time display of simulation results, and lets you interactively alter parameters. $595. **Intusoft**, San Pedro, CA. (310) 833-0710. **Circle No. 314**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3D electromagnetic simulation software runs under Windows. Suitable for analyzing circuits from dc to over 100 GHz, IE3D runs on PCs. According to the company, the software has runtimes less than those of competitive workstation products. The software uses a full-wave integral equation and a method-of-moments algorithm to achieve the fast runtimes. From $5000. **Bay Technology**, Aptos, CA. (408) 688-8919. **Circle No. 316**

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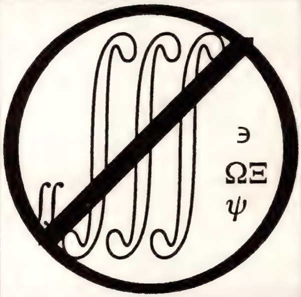

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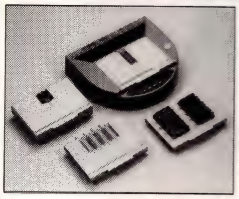

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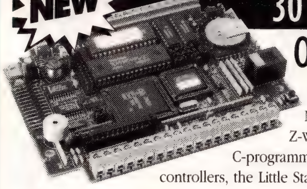

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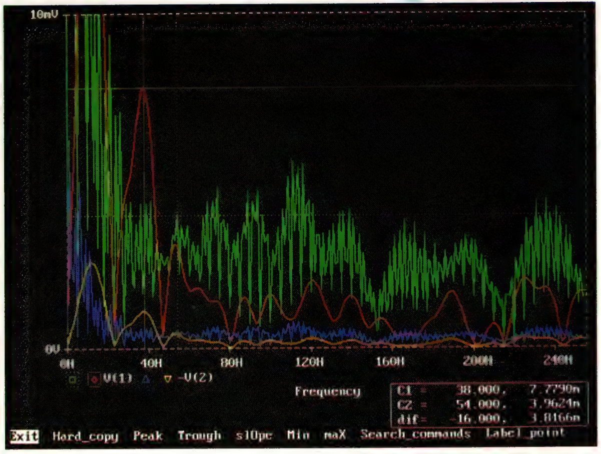

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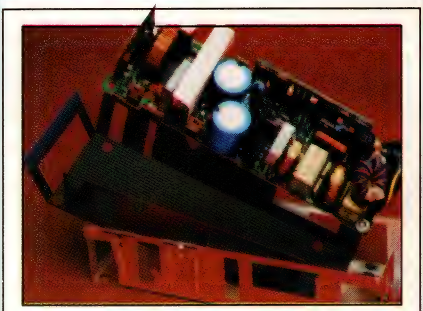

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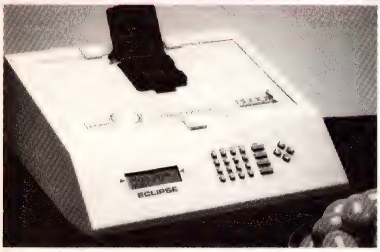

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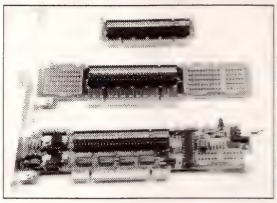

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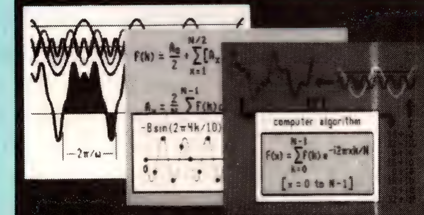
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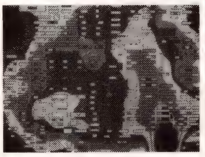

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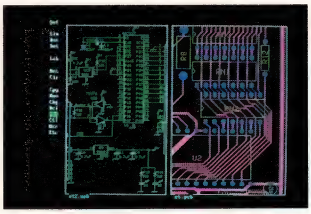

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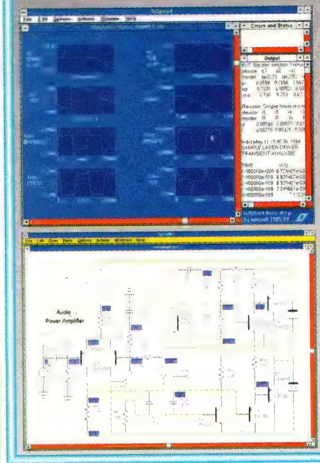

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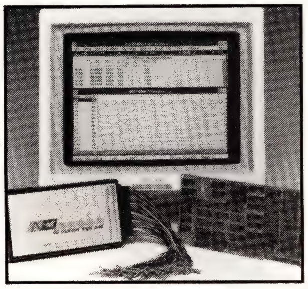

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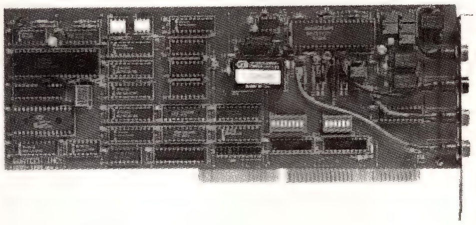

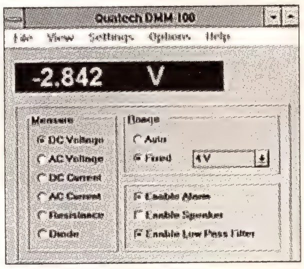

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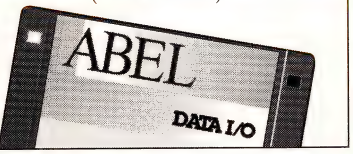

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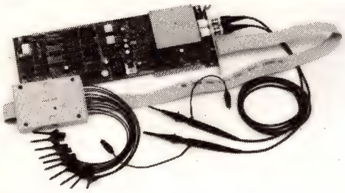

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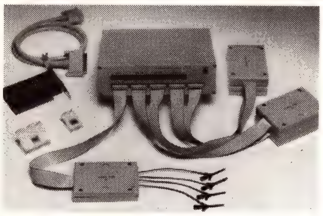

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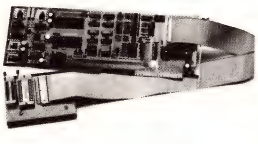

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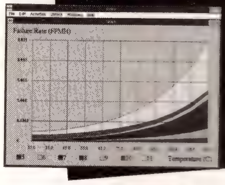

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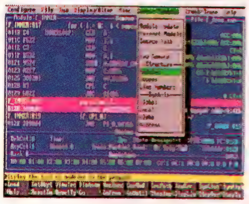

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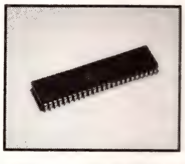

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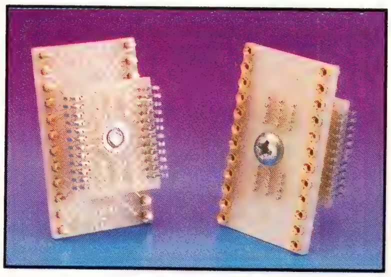

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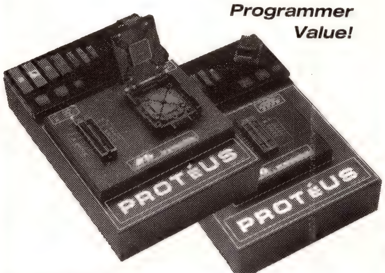

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One-trick ponies?

“I've been told by quite a few people not to discuss this topic publicly,” says Joe Costello, CEO of one of the world's largest EDA companies: Cadence. “Other EDA CEOs said not to discuss it because it'll only anger customers. The PR people carefully tried to tell me to avoid this topic altogether because of ‘negative customer reaction.’ My big customers warned me not to discuss this with other customers because they probably won't like what's being proposed. Even my lawyers said not to talk about this because it might violate some antitrust law—and that the customers won't like it,” said Costello in a recent phone interview.

Costello isn't trying to publish some closely held business secret like the formula for Coca-Cola. No illegal diversion of federal funds or North Korean nuclear-weapon plans involved here. Joe just wants to challenge how the EDA industry views its software pricing, support costs, funding new software development, and paying for upgrades. If the industry won't meet his challenge, he at least wants the engineering community as a whole to reexamine this topic seriously.

> **“Even my own lawyers said not to talk about this because it might violate some antitrust law—and that the customers won't like it!”**
>
> **Joe Costello, CEO, Cadence**

Turnkey pricing

Historically, EDA companies sold hardware and software together as a turnkey package. Early on, it was much easier to convince a purchasing manager to fork out the $30,000 in capital expense for a workstation that he, the accounting department, and the IRS could physically put their hands on. Even nontechies knew that workstations had fairly well-defined product life spans that fit rather nicely into standard IRS-acceptable depreciation schedules. EDA software, on the other hand, wasn't something you could touch, was easily copied, and had a problematic quasi-indefinite life span that wreaked havoc on accounting depreciation tables. *Let's just ask those EDA salesmen to throw in the software for free, OK?*

Of course, everyone also agreed with the concept of paying EDA companies “protection money,” in the form of annual maintenance fees of 12 to 15% of the purchase price, to keep hardware (and software) running smoothly. This bought the right to phone the EDA company when things didn't work—and even have technicians sent out if things got really bad. You need experienced hands to keep the electronics functioning. And software “repairs” weren't real anyway, just an occasional tape sent for free from some address in California.

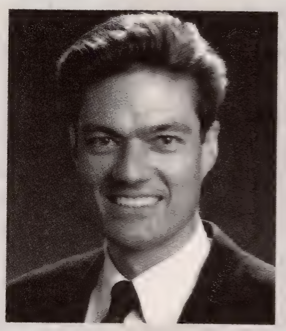
After a few years, better workstations emerged that made old workstations look, well, old. “‘No problem!” says the company accountant, “Just buy new workstations. I'll depreciate all the old ones!” Management then, to the glee of the EDA vendor, approved big bucks for the purchase of new EDA workstations—and new EDA software.

As time went by, the EDA industry changed. Eventually, the EDA vendors got out of the hardware business altogether because customers wanted *one* workstation with *one* operating system that a variety of different EDA and gaming software packages could run on. Also, accounting departments became more sophisticated on how to handle software purchases. The trick is to buy EDA software the same way we bought workstations: *Purchase price plus the annual protection money to keep those tapes arriving from that address in California!*

Here's where Costello stepped in with some observations: “This business model works great for the first few years if you have a hot product that's flying like a rocket ship to the stars. You make your money selling licenses for $25,000 a copy. The 12% annual maintenance fee rarely covers the actual expense of staffing a hot line plus development of the next generation of tools; no one's complaining when you get 33% pretax profits on sales.

“The gotcha comes when you've sold your

hot product to customers that expect the next generation of the product to be covered by the 12% annual maintenance fee. If you look at it, you see it's a bankrupt strategy because you never get the influx of cash that used to come when the customer bought new EDA hardware and software in the turnkey pricing model.



"This dooms all EDA companies to being purely one-trick ponies," Joe says, "where new companies cycle in to supplant the old companies purely out of a poorly thought-out EDA-industry business model."

Joe Costello, "Grand Pooh-Bah of Cadence"

"Instead," said Costello, "customers develop elaborate schemes to get maximum use out of EDA software with an eye on paying minimal dollars to the EDA companies. Exemplifying this are customers who demand floating licenses in lieu of buying extra fixed licenses. This absorbs tremendous demand for EDA software while successfully keeping money out of the EDA vendors' budgets. I even have customers who are talking about floating licenses across T1 lines so they can run one license over three rotating world shifts: first in Europe, next in the US, then in Japan...and then back to Europe! Where does the EDA vendor win—or possibly break even—with this business model?"

Costello went on to describe an industry scenario where customers who pay maintenance fees establish a double standard, which I witnessed a few months back: In a small-scale Cadence customer rebellion on the Internet news groups *comp.lang.verilog* and *comp.cad.cadence*, engineers complained about being asked to pay $10,000 to upgrade their Verilog-XL license to Turbo-Verilog. Established customers had no qualms with Cadence's charging new customers the extra $10,000, but, because they paid maintenance fees all these years, the long-term customers felt the upgrade should be free.

The double standard that Costello pointed out is that a completely new company like Chronologic can offer a Verilog upgrade for a higher price and customers don't balk because they're buying a "new" EDA tool. "This dooms all EDA companies to being purely one-trick ponies," Costello said, "where new companies cycle in to supplant the old companies purely out of a poorly thought-out EDA-industry business model."

A secret marriage

Before you get teary-eyed and pull out your corporate checkbook to support the EDA vendor of your choice, there are some other factors an EDA consumer should be aware of. During the interview, I did some back-of-the-envelope calculations to figure out how much money Cadence made from selling Verilog. I came up with a total of $250 million for a 7-year period. Verilog was a real cash cow for Cadence. Yet, five guys in a start-up called Chronologic wrote a screaming Verilog simulator in 15 months.

What's unstated in Costello's overall observations is that he's seeking an unwritten contract that, once you make a significant purchase from an EDA company, you are making a commitment to that vendor for better or for worse. This means that you're giving this EDA company control of your design process, even though its goals may not always match yours.

With a quarter of a billion dollars in Verilog income, Cadence could have easily spun off a compiled Verilog project. Instead, it used that cash to finance all sorts of projects, many of which were against customers' own vested interests! That is, a customer that has tens of thousands of man-hours invested in using Verilog design methodology isn't particularly well served when Cadence takes Verilog income to finance a VHDL simulator to sell for new-license income. Or how about the Synopsys/Cadence customers who see Cadence Verilog dollars going into writing a competing synthesis tool? (Synopsys is no saint either—it used Verilog-synthesis dollars to finance a VHDL simulator and an ATPG tool, among other products.) The point is that sometimes big EDA company's vested interest is to sell any type of license to keep cash flow positive.

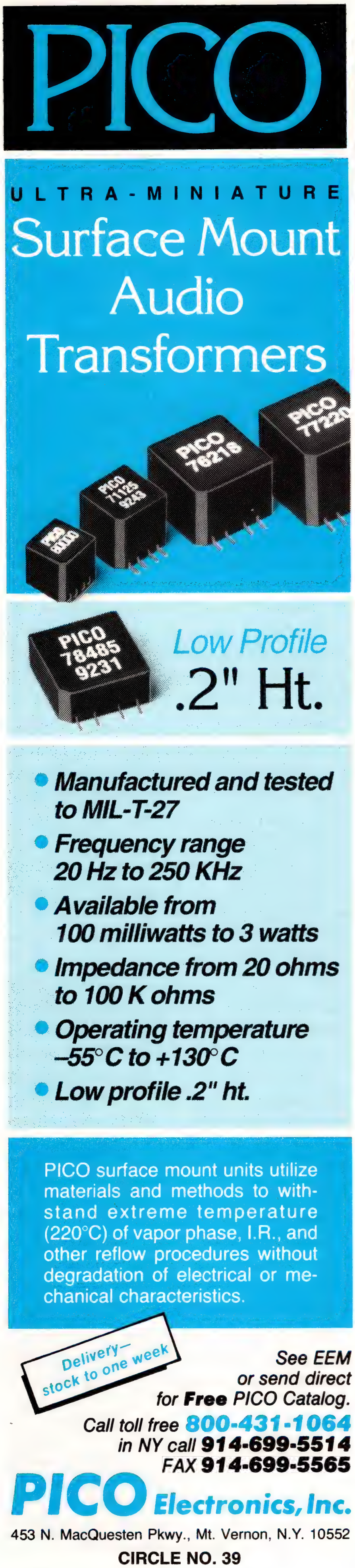
The positive side of helping small EDA companies is that virtually all of your EDA dollar goes to where you think you're putting it. That is, if you buy an ATPG tool from Sunrise Test, your money most likely isn't going to be financing a new schematic-capture tool, because the company is concentrating on keeping its ATPG tool competitive.

To remedy the situation, Costello is experimenting with spinning off companies for new products, as opposed to keeping them an incorporated part of Cadence. Instead of absorbing Comdisco and newly purchased Redwood, Cadence is merging the two companies into one business unit named Alta, which will retain its own sales staff, R&D team, and support group.

A second way Costello is thinking about remedying the problem business model is to adopt the PC software pricing-and-services way of doing business. Customers buy a specific version of an EDA tool. If they want an upgrade, they pay for it. Also, customer service is broken into various support levels—all based on what the customer pays for in support.

Costello closed the interview with an interesting statement: "Although absolute dollars in the EDA market have grown steadily over the past seven years, you'll find that the percentage investment by EDA consumers for EDA tools has decreased by 50% in those same seven years. Seven years ago, electronics companies used to spend 2% of budgets on EDA tools; now they spend only 1% of their budgets on EDA tools."

John Cooley, an EDA consumer advocate and founder of the outlaw E-mail Synopsys Users Group (ESNUG), lives on the Holliston Poor Farm in Massachusetts. He raises sheep and is an EDA- and ASIC-design instructor and project-in-crisis consultant. He can be reached at "jcooley@world.std.com" or at (508) 429-4357.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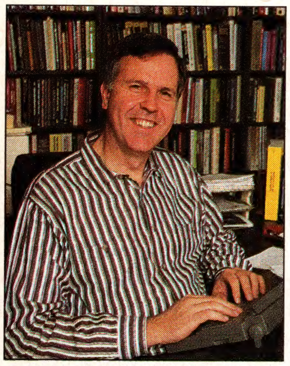

DAVID BRUBAKER, FUZZY LOGIC CONTRIBUTING EDITOR

Fuzzy logic

The μP of tomorrow?

Several years ago, Steve Marsh, director of strategic operations at Motorola (Austin), visited Japan. Having checked into his hotel, he had only enough time to drop his baggage in his room before hurrying to dinner with a customer. He entered the elevator and pushed the button of his floor. The elevator doors closed, and, in a few seconds, opened again. Thinking that someone had pushed the elevator-request button, Steve held the door open and looked out, but no one was waiting. When he reached again to push the button for his floor, he discovered he was already there. The elevator had transported him several floors without his feeling any motion.

Being an engineer, Marsh was intrigued, so he commandeered the elevator and played awhile, moving between floors, both short and long distances, both up and down. Concentrating now, he could feel the car moving but was amazed at the lack of its jerk in both starting and stopping and at its smooth acceleration and deceleration. I don't know whether Steve made it to his dinner on time, but he later had Motorola personnel inquire about why the elevator's movement was so smooth. The explanation was simple: Fuzzy logic controls the elevators. Steve became a believer.

Allowing logic to be fuzzy lets us get our arms around systems that have defied understanding.

What is this serious technology with the funny name? In its most general definition, "fuzzy logic" is the mathematical basis, formulated and named nearly 30 years ago by University of California, Berkeley, Professor Lotfi Zadeh, that allows for shades of gray, or "fuzziness," between absolute truth and falseness. In fuzzy logic, an assertion can be partially true, and, if so, can also be partially false, to the degree that it is not true.

This simple-sounding concept has become a rather dramatic springboard. By stepping beyond the black-and-white world of bilevel logic and into the shades-of-gray world of fuzzy logic, we become better-equipped to deal with uncertainty, vagueness, imprecision, nonlinearities, and even time variance; in short, fuzzy logic helps us deal with much of the real world. Allowing logic to be fuzzy gives us greater ability to get our arms around systems that in the past had defied understanding.

Extending this definition, are fuzzy logic systems logically those that in some manner employ this mathematical basis? The answer is, "yes and no." Yes, in a general sense, and no, because, over the last few years, the phrase "fuzzy-logic system" has come almost exclusively to mean a rule-based system with rules stated as relationships between fuzzy variables. These fuzzy rule bases, which we will detail in future columns, are at the heart of many systems in diverse applications. Even in this country, which lags behind both Japan and Europe in fuzzy engineering, fuzzy products are starting to emerge. For example, General Motors Corp uses a fuzzy controller for the Saturn's automatic-transmission downshift mechanism, and Liebert Industries uses one in its LogiCool temperature and humidity controller. Metus Systems uses fuzzy logic in a fraud-detection system for health-care providers, and Delta-X Research developed and sells a Windows-based program that uses a fuzzy version of an IEEE/ANSI standard to analyze faults in large electrical-power transformers. Many more fuzzy-development projects are under way.

Having touched on what fuzzy logic is, I should also mention what it is not. It is not probability, although both fuzzy logic and probability deal with uncertainty. It is also not neural nets, although the two technologies work well together. And it is not artificial intelligence: Although adaptive fuzzy systems can and are being implemented, basic fuzzy systems are deterministic. Fuzziness does not imply learning.

PHOTOGRAPHY / LIANE ENKELIS

Where is fuzzy logic headed? I see a historical parallel.

In late 1973, I was a young engineer less than a year out of a master's program in electrical engineering and working in a group that designed satellite attitude-control systems for TRW Defense and Space Systems in Redondo Beach, CA. First-generation μPs were available, off the shelf, from Fairchild, Intel, National Semiconductor, and Rockwell International, with other vendors scrambling to introduce their devices. The trade journals, including *EDN*, were just starting to publish articles that gave glimpses into the μP's early potential.

Fuzzy logic has the potential to have the same impact on technology over the next two decades that the μP has had over the past two.

I found the new technology exciting. One lunch hour, I consumed a detailed introductory article and wanted to tell someone what I had learned. In the lab, I found Bob, a senior engineer, sitting at one of the benches troubleshooting a hybrid analog/digital breadboard with an oscilloscope.

As I recounted details from the article, Bob didn't stop probing his circuit, but he did listen. After a few minutes, I paused for a breath, and he said, "But how would *we* use it?" I thought for a moment and realized with some embarrassment that I didn't know. As I recall, the article had an example of a μP-controlled butcher's scale, including an illustration complete with a pork chop, but that seemed far removed from the complex control systems with which we worked.

Saying I would get back to him, I retreated to my office. Lunch hour was over, and I resumed work, still pondering Bob's question. Finally in midafternoon, it hit me. I trotted into the lab. Bob was still there, still probing. "I know what you can do with the computer on the chip," I told him. "A μP could simulate the circuit you are working on right here at the bench. You wouldn't have to separate development and analysis. It could all be done right here!" I had seen the light. It seemed so obvious. Amused, Bob looked at me and said, "I'll pass."

I don't recall how long it was before I realized that simulating the circuit was a side issue, that a μP-based system would in a few years *replace* the circuit Bob had designed. Bob eventually realized it too and accepted it, as well, as analog attitude-control systems became things of the past.

Moral: It is very difficult to predict what impact, if any, a new technology will have. We can remove the blinders we wear, firmly cemented in place by years of education and experience, only with great effort, even from those of us who are actively trying to do so. We can make well-thought-out, well-supported claims, but, like my μP-as-a-simulator prediction, they often miss the real mark.

We know μPs first largely replaced random logic and low-frequency analog circuits. Their real power soon became evident at the core of new, powerful user interfaces that were previously infeasible. And they are the basis for PCs and workstations—where they are often called on to perform simulations, Bob! Even a simple piece of electronic equipment now contains a μP, and complex equipment—cars, for example—have many. A decade ago that a product contained a μP and was, therefore, "computer-controlled," was still a valid selling point. Today it's ho-hum.

Fuzzy logic has the potential to have the same impact on technology over the next two decades that the μP has had over the past two. Having observed how it successfully applies to disparate applications in disparate ways, I can see fuzziness creeping into much of what we as engineers do. It will become both a design and an analysis tool in our tool bags and will positively affect many of our traditional tools, as well. In time, fuzzy logic will enable us to solve not only those problems that would be impossible to solve without it, but also those that we do not even see today.

There are those who disagree. Fuzzy opponents say that a traditional, nonfuzzy-control approach would do just as well, if not better, in controlling the Japanese elevator in which Marsh rode. They also say there is nothing fuzzy logic can do that traditional techniques cannot do as well or better. Fuzzy proponents strongly disagree. There are intelligent, well-meaning individuals on both sides. There is also rhetoric—sometimes entertaining and sometimes not—from both sides. While not wanting to appear aloof, I choose not to participate in these debates; those who use the technology—not those who debate it—will ultimately decide the issue.

I am delighted that *EDN* has given me the opportunity to write this column. My primary goal in doing so is to help those of you who are interested learn how to apply fuzzy logic in engineering solutions. At the advice of *EDN* editors, the next six or so columns will be tutorial. We will decide then which direction to take.

By "we" I also include you, the readers. I welcome your comments, observations, and suggestions. EDN

David Brubaker is president of Huntington Advanced Technologies, 883 Santa Cruz Avenue, Suite 31, Menlo Park, CA 94025-4608; or on the Internet at: brubaker@cup.portal.com.

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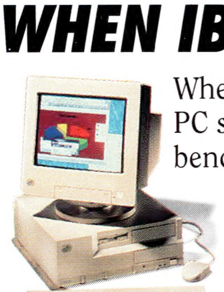

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